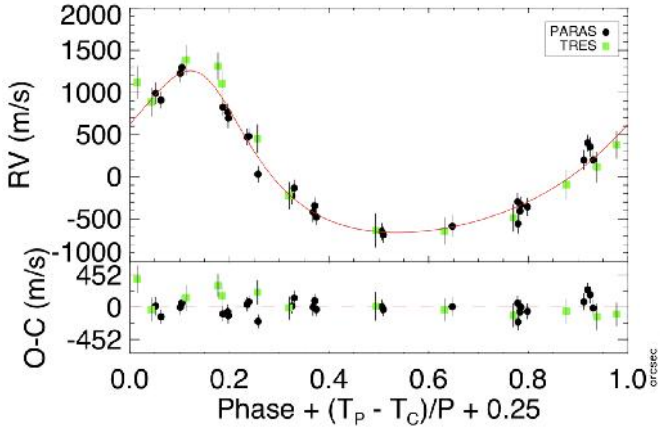
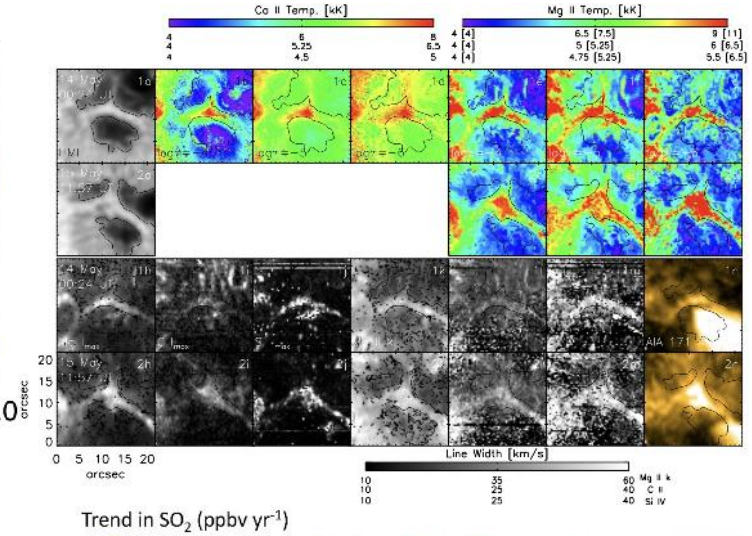
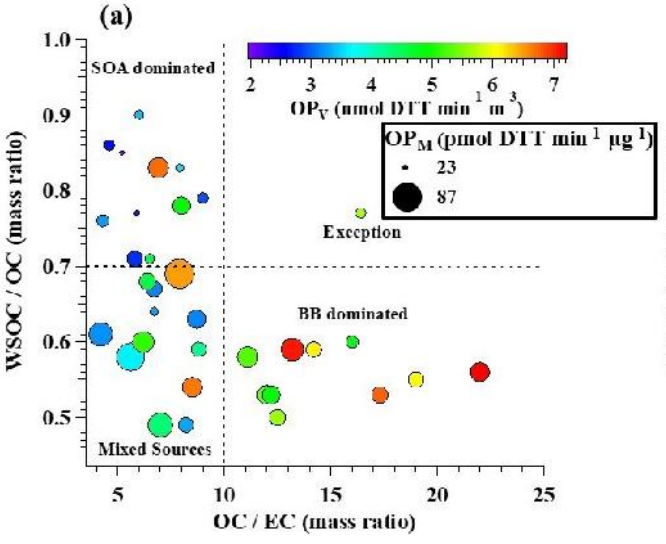
भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद

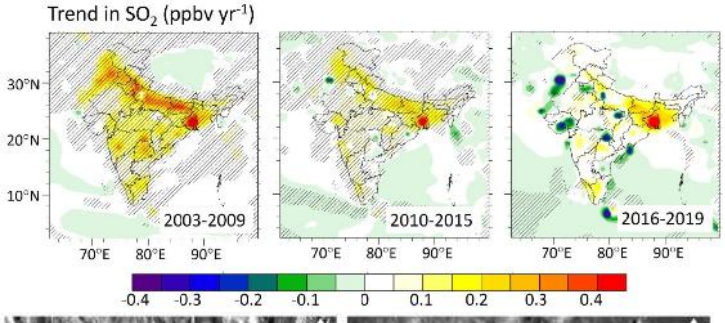
Physical Research Laboratory, Ahmedabad

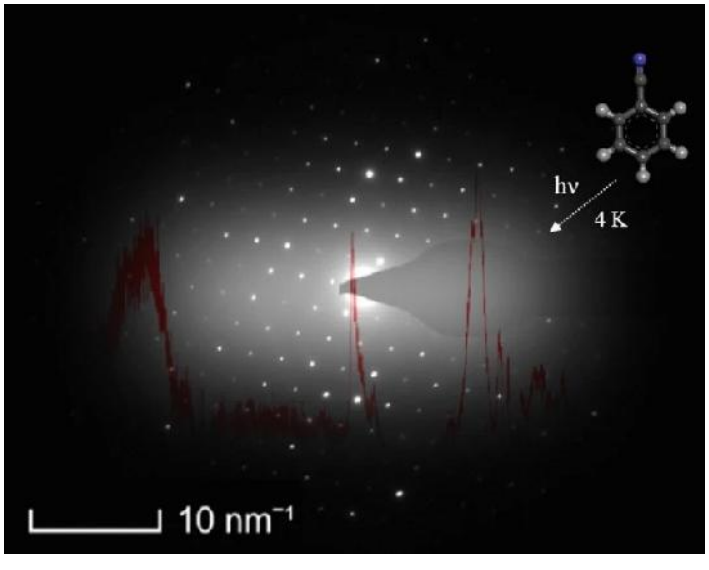
प्लेटिनम जयंती 1947 2022 PLATINUM JUBILEE

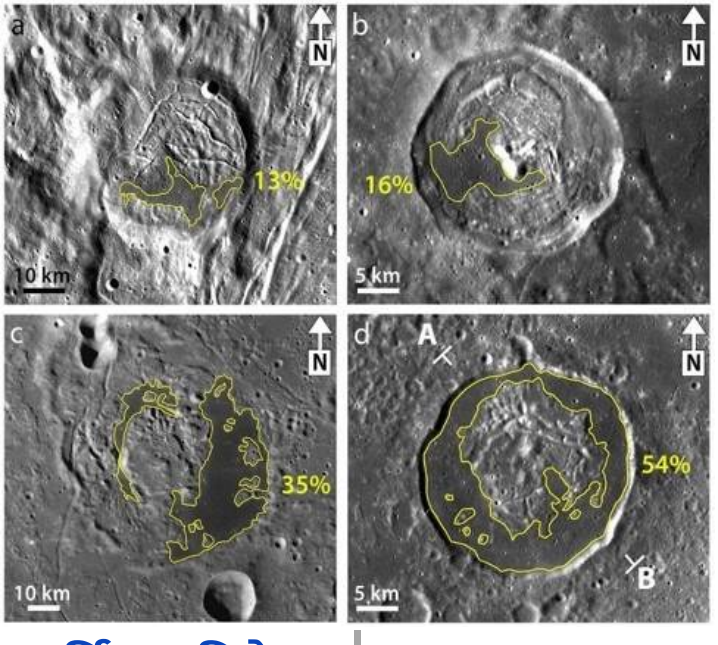










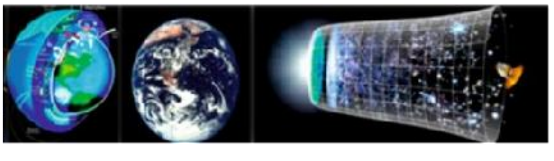


वार्षिक प्रतिवेदन

Annual Report

2022-2023

आज़ादी का अमृत महोत्सव



Front cover page:

Top Right Panel: Sustained Heating of the Chromosphere and Transition Region Over a Sunspot Light Bridge

Top Left Panel: TOI 4603b, a Massive Giant Planet and most dense Exoplanet Discovered with PARAS Spectrograph

Center Right Panel: Trends in sulfur dioxide over the Indian subcontinent

Center Left Panel: Oxidative Potential and Hydroxyl Radical Generation Capacity of Ambient $PM_{2.5}$ over a High-Altitude Site in Northeastern Himalaya: Role of Long-Range Transport

Bottom Left Panel: N-graphene synthesized in astrochemical ices

Bottom right Panel: Mare filled craters on the Moon

Inside back cover pages: Events at PRL

Back cover page:

PRL campuses with official logo of PRL's platinum jubilee celebrations

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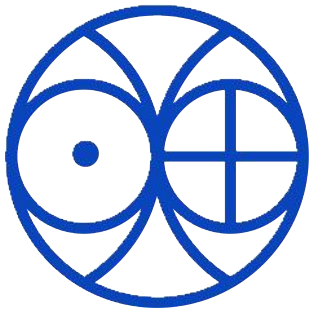
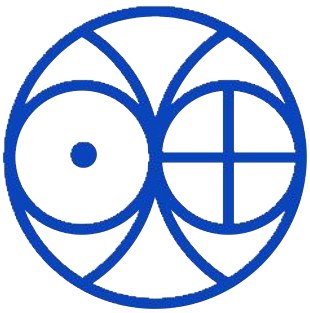


PRL Annual Report

2022 – 2023



PRL research

encompasses

the Earth, the Sun

Immersed in the fields

and radiations

reaching from and to infinity,

all that man's curiosity

and intellect can reveal

PRL Council of Management

Three nominees of the Government of India

1. Shri A. S. Kiran Kumar Dr. Vikram A Sarabhai Professor, ISRO Antariksh Bhavan, New BEL Road Bengaluru-560231	Chairman
2. Shri. S. Somanath, Secretary, Department of Space, Govt. of India Chairman, ISRO Antariksh Bhavan, New BEL Road Bengaluru-560231	Member
3. Shri M. Maheshwar Rao, IAS Additional Secretary & FA Department of Space, Govt. of India Antariksh Bhavan, New BEL Road Bengaluru-560231	Member

A nominee of the Karmakshetra Education Foundation

4. Shri Kartikeya V. Sarabhai Director, Centre for Environment Education Ahmedabad-380054	Member

A nominee of the Ahmedabad Education Society

5. Shri Sanjay S. Lalbhai Chancellor & Chairman, Board of Governors, Ahmedabad University, Ahmedabad-380009	Member

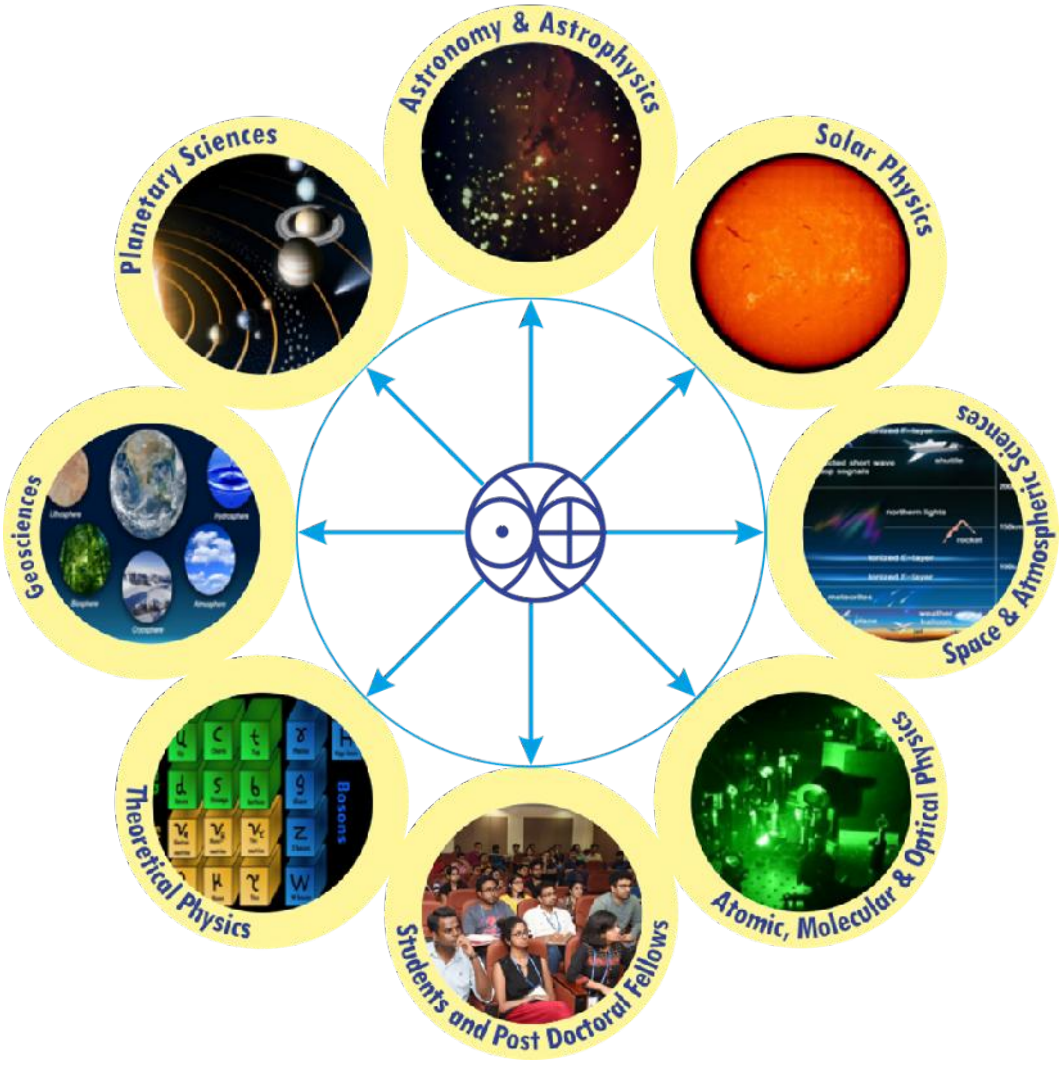
A nominee of the Govt. of Gujarat, Gandhinagar

6. Shri Mukesh Kumar, IAS The Principal Secretary Education Dept. (Higher & Technical Education) Government of Gujarat, Gandhinagar	Member

Physical Research Laboratory, Ahmedabad

7. Dr. Anil Bhardwaj, Distinguished Scientist & Director	Member (Ex-Officio)
8. Prof. R. D. Deshpande, Sr. Professor & Registrar (From 01.01.2023)	Member - Secretary (Ex-Officio)

Areas of Scientific Research and Activities



Contents

From The Director's Desk

As I write this in 2023, I am reminded of the fact that 11 November 2022 is an important landmark for PRL as it marks the completion of 75 years of PRL formation. On this momentous occasion, we pay homage to the visionary leader and founder of PRL, Prof. Vikram Sarabhai, and the founder Director, Prof. K. R. Ramanathan, for their vision and leadership. We stand tall on the solid foundation laid by them and the illustrious alumni of PRL over the past seven and half decades.

Along with the country, PRL too celebrated its own Amrut Mahotsav — the 75 years of PRL — through the PRL ka Amrut Vyakhyaan (PKAV) that started on 4 August 2021, with a sankalp of having a PKAV every Wednesday at 4 pm. We successfully completed the 75 weekly PKAVs, without a single break, on 5 January 2023: a record in itself. The speakers of the Vyakhyaans included Nobel Laureates, Fellows of the Royal Society, Secretaries of Departments of Govt. of India, internationally renowned experts in various fields, Presidents of National Academies, and policymakers, covering various branches of sciences, engineering, medicine, management, law, culture, sports, and arts. All these Vyakhyaans are freely available on PRL's YouTube Channel and are truly a treasure trove. Now, PKAV 2.0 has begun on 30 January 2023, having one PKAV every month, and it's going on in full swing.

Over the last one year, PRL has produced nearly two hundred seventy research publications in high-impact peer-reviewed journals and 27 PhD theses, apart from contributing very significantly to the development of payloads for the Chandrayaan-3 Lander and Rover mission and the Aditya-L1 mission. The level of commitment displayed by the PRL faculty and staff in carrying out research, producing high-quality space-borne experiments, in-house instrumentation development, detailed laboratory analysis, and intense academic and scientific programs has been phenomenal. These efforts have been recognized through awards and honours. PRL research scholars have received best paper awards for presenting their research work in national and international scientific conferences, and some have also won the best thesis award. PRL faculty have received more than two hundred invitations to give invited talks and lectures at conferences, symposia, workshops, and academic and research institutions. For me, this is a matter of great pride and satisfaction on the commitment shown by the industrious and talented group of faculty and staff of PRL.

The new 2.5 m telescope facility at Mt. Abu has become operational in December 2022. Several back-end instruments, including PRL Advanced Radial-velocity Abu-sky Search spectrograph PARAS-2, are in commissioning and operation.

Several new and vital scientific findings have been obtained during the year 2022—2023.

A new Jupiter-sized exoplanet, called TOI4603 or HD 245134, has been discovered by PRL scientists. It has the highest density of 14 g/cm^3 known to date and a mass of 13 times that of Jupiter. This massive exoplanet was discovered using the indigenously developed PARAS-1 attached to the 1.2 m telescope of PRL at its Gurushikhar Observatory in Mt. Abu.

The differential emission measure (DEM) analysis of the quiet Sun X-ray emission using observations from the PRL-built Solar X-ray Monitor (XSM) on the Chandrayaan-2 orbiter mission, and SDO/AIA, for the first time, showed two different temperature components having temperatures of 1 MK arising due to the diffuse corona and 2 MK arising due to the X-ray bright points (XBP), respectively.

A detailed study of the optical and X-ray properties of Be/X-ray binary pulsar 1A 0535+262 during its recent giant X-ray outburst was carried out using data from PRL's 1.2 m telescope at Mt. Abu and Indian AstroSat. The observed prominent H_α line in the optical spectrum is found to be significantly variable. The study suggests that the presence of a warped circumstellar disc around the Be star to be the cause of giant X-ray outburst in the Be/X-ray binaries.

The AstroSat observation of the black hole candidate MAXI J1803-298

on 2021 May 11—12, revealed the presence of four periodic absorption dips with a periodicity of 7.02 hours in the light curve. We estimate the mass function of the system as f(M) = 2.1 — 7.2 solar mass and the mass of the black hole candidate in the range of 3.5 — 12.5 solar mass.

A study was conducted comprising of three homologous compact major blowout-eruption solar flares. The sequential eruption of flux rope system led to the homologous flares, each followed by a CME, which gradually attained large angular width in the outer corona. In this context, a generalized' Magnetic-Arch-Blowout' scenario was invoked to explain the underlying physics of formation of broad CMEs resulting from compact eruption-source site, providing useful inputs toward the near-Earth space-weather prediction.

The helium abundance is about 8 percent at the solar photospheric/chromospheric heights, but is higher in interplanetary coronal mass ejections (ICMEs) on many occasions. Based on an extensive analysis, we have shown that chromospheric evaporation in tandem with gravitational settling determines variabilities in helium abundance beyond 8 percent in ICMEs.

Analysis of around 1300 all-sky images at atomic oxygen 630 nm emissions from Kolhapur, revealed that scale sizes in the range of 250—300 km seem to be the thermospheric natural behaviour. However, during times of bubbles, shorter scales in the range of 50—250 km, were observed which drifted eastwards with speeds of 13090 ms^{-1}. It is inferred that shorter scale size gravity waves play a significant role in seeding the perturbation of the equatorial plasma bubbles, which cause disruption in radio communication.

Using Krassovsky's method we have investigated terdiurnal, large- and small-timescale gravity wave characteristics using nocturnal variations of the OH (3-1) brightness and its rotational temperatures measured with indigenously developed PRL Airglow InfraRed Spectrograph. Using single altitude observations amplitudes, phases, Krassovsky parameters, and vertical wavelengths of the terdiurnal tide and GWs were derived. This study demonstrates that the dynamics of the MLT region are influenced by upward propagating waves having different wave characteristics which are present at different times throughout the night.

Analysis of high-quality, two-decade long ground-based and satellite data since 2001 of aerosols and their radiative effects from several locations in the Indo-Gangetic Plain in South Asia and the North China Plain in East Asia, revealed a clear divergence in the trends in aerosol optical depth. The single scattering albedo is increasing, and the absorption AOD due to carbonaceous aerosols is decreasing over both the regions, confirming that aerosols are becoming more scattering in nature over Asia. Aerosols in fine mode have increased whereas coarse mode natural aerosols have declined, which are attributed mainly to changes in anthropogenic aerosol emissions, and not to natural and climatic factors as their changes are relatively small.

Fundamental changes in thermal and mantle melting regime in the Moon through time have been observed using the studies of lunar meteorites (3.9—4.35 Ga). The study explored the possible mechanisms through which these KREEP (K(Potassium), Rare Earth Elements, and Phosphorous)-free lunar basalts might have been formed. Importantly, the calculation indicates that the energy generated by radioactive materials alone cannot be a major driving force for the lunar magmatism, especially for the KREEP-free lunar rocks formation. Instead, these ancient KREEP-free lunar basalts might have been formed from low-pressure decompression melting in the Moon.

A meteorite fallen at Diyodar Taluka, Banaskantha district, Gujarat on 17 August 2022 has been classified by PRL scientists as a stony achondrite breccia with a predominant constituent of white pyroxene grains of various size and shape. The dominant mineral phase is enstatitic pyroxene, while diopsidic pyroxene is also present as the next dominant phase. Olivine is forsteritic, and plagioclase is albitic. The sample contains various sulphides. Preliminary description and study suggest that the meteorite is a rare, unique specimen of Aubrite.

Plasma and magnetic field data obtained from 627 orbits of Mars Atmosphere and Volatile Evolution (MAVEN) that occurred during October 2014, April 2015, September 2017 and May 2018, when the spacecraft was crossing the magnetic pile-up boundary of Mars, have been analyzed. A steep ionopause–like boundary is observed, when MAVEN was passing from the magnetic pile-up region during the daytime ionosphere in the presence of high strength of horizontal magnetic field, while their night side ionosphere did not show such boundary. It is proposed that the horizontal magnetic field can form such ionopause within the magnetic pile-up boundary during the daytime if time and location of the magnetic anomaly coincide with the ion and electron density measurements.

A total of 23 potential caves have been discovered in the Elysium Mons region of Mars on the basis of morphology, geological context, and thermal behaviour of the region determined from CTX, HiRISE, MOLA, and THEMIS data. Further, cave entrance has been detected in nine candidates. These sites could be important destinations for future robotic/human exploration and the search for life on Mars.

Black carbon concentrations and its isotopic compositions in a sediment core retrieved from the Wular Lake (Jammu and Kashmir) revealed precipitation and fire history in the region for the past 4000 years. The study revealed two distinct climatic phases in the region characterized by a dry phase during 3750—1500 Cal years BP (Before Present) and a wet phase during 1500—300 Cal year BP. These results, in combination with available studies from the region, suggested that forest fires in the Kashmir Himalaya during the study period were dominantly human-driven rather than that caused by large scale climate change.

A stalagmite from Belum cave (Kurnool district, Andhra Pradesh) was used to retrieve past signatures of monsoon fluctuations from $\sim$183 ka to $\sim$175 ka and $\sim$104 ka to $\sim$82 ka. Variability in stable oxygen and carbon isotope compositions and trace element concentrations shows that processes occurring in the southern hemisphere on millennium time scale affect the Indian monsoon strength. The cross-equatorial flow of moisture, caused by atmospheric pressure gradient is a possible process that sends climate signals from the southern hemisphere to the northern hemisphere.

Oxidative potential (OP) of aerosols was studied over Shillong. Results suggest that the OP of aerosols (mainly organics) increases with their aging. It implies that toxicants emitted over a source region (such as from biomass burning emissions in northern India) become more toxic during the long-range transport, as observed over Shillong.

A detailed stable isotope-based analysis depicted that the summer season evaporative loss was $\sim$58% of the Ganga water in its middle

plain segment (length around 1200 km) in 2019 and an increase of about 120% of water near the end of the middle segment compared to that started at the beginning. Our field observation and in situ groundwater data indicate that the recent decrease in Ganga water flow in summer was due to artificial diversions, a decrease in inflow from tributaries and increased human interventions.

Analytical description of propagation of unstable neutrinos in matter is worked out for the first time. The probabilities of conversion of neutrinos from one type to another during such propagation are obtained in compact form for both two and three flavour cases.

It is pointed out for the first time that extra interactions of neutrinos can help in energy deposition in the gamma ray bursts. From this analysis, constraints were obtained on the corresponding interaction parameters.

Grand Unified Theories (GUT) which unify the strong, weak and electromagnetic forces predict existence of several spin-less particles and also their interaction strengths with the quarks and leptons. Extensive analysis of SO(10) based GUT has been carried out to investigate the role played by these new particles in the rare processes like nucleon decays, baryon-antibaryon and meson-antimeson oscillations. Results show that the estimated lifetime of some of these processes are quite different from typical expectation based on simplified models and assumptions.

Several ways have been adopted in the literature to generate non-Bardeen-Cooper-Schrieffer (BCS) Cooper pairs (CPs), but it is always extremely hard to protect any non-BCS CP from being contaminated by BCS and other non-BCS CPs. We have shown how to solve this two-decade old problem in a topological Josephson junction. We are able to generate one of the essential non-BCS CPs (100%) free from any contamination. Our work also offers a highly tuneable detection scheme for the same CP.

Our results on quantum key distribution (QKD) through the atmosphere show that the concentration and extinction coefficient of atmospheric aerosols play a major role in influencing the key rate in QKD. Such experiments are important to validate the models to account for the atmospheric effects on the key rates achieved through satellite-based QKD.

Investigation as to how shocks may induce physico-chemical transformation in amorphous carbon has been carried out using PRL's High speed shock tube by subjecting samples of carbon nano-powder to high-temperature shocks, $\sim$7300 K, in a hydrogen-free environment for about 2 ms. The shock conditions achieved in the laboratory mimics low velocity interstellar shocks. Post shock samples were analyzed using Raman Spectroscopy and High Resolution Transmission Electron Microscopy. Compelling evidence has been found for the formation of carbon nanotube, graphene, and various other carbon nanostructures induced by the shock. These results show that shocks in the interstellar medium can provide important chemical pathways to the formation of fullerenes and suggests that other carbonaceous structures may be present as well.

Femtosecond laser pulses induced strong-field ionization of CH3Cl is studied using an in-house developed Cold Target Recoil Ion Momentum Spectrometer (COLTRIMS) setup. Four two-body breakup pathways of CH_3Cl^{2+} have been identified. It is observed that the yields of two-body pathways decrease by increasing the intensity, which was attributed to enhanced ionization of the dication before it can dissociate.

A crucial step towards realization of Quantum Computing in the context of many-electron systems requires a rigorous quantum mechanical treatment of different interactions. A pilot study has been carried out to investigate the physical effects beyond the mean-field approximation, known as electron correlations, in the ground state energies of atomic systems using the classical-quantum hybrid variational quantum eigen-solver algorithm. A salient feature of the study involves a detailed analysis to find the number of shots (the number of times a variational quantum eigensolver algorithm is repeated to build statistics) required for calculations with IBM Qiskits QASM simulator back-end, which can mimic an ideal quantum computer.

PRL continues to be strongly committed towards popularization of Science. In this endeavour, PRL celebrated National Science Day (NSD) 2023 in two phases. In Phase 1, PRL's members visited 19 different centres across Gujarat and conducted a screening test for the Aruna Lal Scholarship on 22 January 2023 wherein 163 schools were covered. Close to 1000 students participated with about 50% being girl students. In Phase 2 of the NSD, the students shortlisted from the screening exam were invited to PRL on Saturday, 25 February 2023 wherein over 150 students and 60 teachers/accompanying parents attended. Interviews for the Aruna Lal scholarship was also held on this day. To mark the platinum jubilee celebrations, 75 prizes were awarded, including 5 Aruna Lal Scholarships for 2023. In addition to the tests conducted at different centres for NSD, PRL team demonstrated science experiments through its signature program, the Science Express, wherein around 5000 students were benefitted. Furthermore, the Vikram Sarabhai Protsahan Yojana (VIKAS) Scholarship exam was also conducted at 19 different centres in Gujarat on 22 January 2023.

The National Space Science Exhibition 2022 was conducted in the city of Kolkata during 611 December 2022, wherein PRL showcased its areas of research, and encouraged, especially the student visitors, to take up sciences as their career. PRL also participated in the National Children Science Congress and National Science Day Science carnival at Science City, Ahmedabad, in January and March 2023, respectively, which witnessed a participation of more than one lakh students.

Towards the responsibility of capacity building in niche areas in the country, PRL continues to provide highly skilled researchers through its vibrant Doctoral and Post-Doctoral programmes. In addition, PRL conducts a Visiting Scientist programme for university teachers, and project training for graduate and post-graduate students in both engineering and science to conduct short- and long-term project work. PRL organizes intensive summer programmes for students as well as college and university teachers every year and also partakes through its association with similar programmes conducted by the Indian Science Academies. Through these programs more than 100 students were trained. PRL continues its strong academic association with universities and institutes in Gujarat and all over the country.

This year, PRL organized several conferences and workshops in almost all the areas of research in PRL. These include, Venus Science Conference; Students Conference in Optics and Photonics; Amrut Mahotsav of India's Independence International Asteroid Day; Meteoroids, Meteors and Meteorites: Dust, Ice and Gas

Astrochemistry; Frontiers in Geosciences Research Conference; PRL Conference in Condensed Matter Physics; National Symposium on Shock Waves; and Indian Planetary Science Conference.

All these events contribute to capacity building in various specialized fields of sciences in the country. PRL hosted the 3^{rd} Arvind Bhatnagar Memorial Lecture, the 3^{rd} Bibha Chowdhuri Memorial Lecture, and the 5^{th} PRL-Indian Association of Physics Teachers (IAPT) Vikram Sarabhai Lecture, in addition to the ISRO Structured Training program.

PRL ensures the use of Hindi in all areas of administration and official communications and takes adequate steps in this direction. The website of PRL is bilingual. The work done at PRL in implementation of Hindi in various domains has been recognized by the Town Official Language Committee and DOS.

I am indebted to all the members of the PRL Council of Management for their constant encouragement, invaluable advice and whole-hearted support for all the scientific activities pursued at PRL. In particular, I am grateful to Shri A. S. Kiran Kumar, Chairman, PRL Council, and Shri. S. Somanath, Chairman, ISRO and Secretary Department of Space for their sage advice, unstinted support and encouragement.

Anil Bhardwaj

Director

PRL in News

1. “First model map of the Moons surface and subsurface temperatures, Research Highlight, ’nature india’. https://www.nature.com/articles/d44151-023-00007-1
2. “Group of lunar meteorites suggest a new scenario for the origin of lunar basalts, ISRO story. https://www.isro.gov.in/lunarbasalts.html
3. “Astronomers discover Elusive Dying Radio Galaxies using deep radio surveys, Hindustan times story. https://www.prl.res.in/~notices/websitedocs/2023/03/01/Astronomers_discover_%E2%80%98Elusive_Dying_Radio_Galaxies%E2%80%99_using_deep_radio_surveys_-_Hindustan_Times-01-03-2023-08-35-28.pdf
4. “Scientists develop comprehensive 3D thermophysical model for the Moon, covered by the Hindu. https://www.thehindu.com/sci-tech/science/scientists-develop-comprehensive-3d-thermophysical-model-for-the-moon/article66567779.ece

Science Highlights

Astronomy and Astrophysics

- Time-resolved X-ray spectroscopic analysis of a C-class flare using observations from the Chandrayaan-2/XSM unambiguously established the multi-thermal nature of plasma during the impulsive phase of the flare. The detailed differential emission measure (DEM) analysis showed two distinct temperature components of the plasma, indicating the presence of directly heated plasma by the magnetic reconnection and the evaporated plasma due to the chromospheric evaporation, as two separate components.
- The differential emission measure (DEM) analysis of the quiet Sun X-ray emission using observations from the Chandrayaan-2/XSM and SDO/AIA, for the first time, showed two different temperature components having temperatures of $\sim$1 MK arising due to the diffuse corona and $\sim$ 2 MK arising due to the X-ray bright points (XBP), respectively. Detailed numerical simulations showed that the higher temperature of the XBP can be sustained due to the collective effect of the large number of small-scale impulsive events known as nano-flares.
- Dust is a ubiquitous component in our Galaxy. Although it accounts for only 1% of the mass of the ISM, it is still an essential part of the Galaxy. Dust is most evident in the equatorial lanes of edge-on spirals, making it possible to map the spiral arms and overall structure of the disk by studying its distribution. However, mapping the dust distribution directly in longer wavelengths can be challenging due to distance ambiguity, but properties of dust like extinction and polarisation can be used to create a three-dimensional map. In our study, we have carried out the polarisation observation of a distant cluster, Czernik 3 with the aim to investigate the number of foreground dust layers and their distances along the line of sight. The observations were performed using EMPOL, an EMCCD-based polarimeter on the 1.2 m telescope of Mount Abu Observatory, PRL. By reducing the data using self-scripted automated Python routines, we were able to find the polarisation of 43 stars in the core of the cluster. Our findings showed a large range in the degree of polarisation, indicating non-uniform dust distribution over the plane of the sky. The variation of the observed degree of polarisation with distance suggests the presence of at least two dust layers along this line of sight at distances of $\sim$1 and $\sim$3.4 kpc. However, the large-scale distribution of dust, using the polarisation information of nearby clusters within 15° of Czernik 3, reveals low dust and stellar contents in the inter-arm region between Local Arm and Perseus Arm. The results highlight the importance of using polarisation to map the dust distribution and study the large-scale structure of the Galaxy.
- Comet 156P/Russell-LINEAR is a Jupiter family comet and comes around to perihelion every 6.44 years. Unfortunately, this comet has never been studied in detail because of its unfavourable apparitions. But, during the latest apparition in 2020, astronomers took advantage of the opportunity when they could and used special tools to observe the comet's behavior and composition. A combination of observational techniques including spectroscopy, imaging, and polarisation measurements were used to study the comet's properties. Computer models were also developed to understand what materials the comets dust is made of and how it behaves. From the observations, it was discovered that the comet has strong emissions of certain gases, like CN, C3, and C2. It was also found that the comet has strong jets that shoot out dust particles. Interestingly, the dust particles are mostly made of large grains with low porosity, which means they're more solid and less fluffy than seen in other comets. It was also noticed that the comet's polarisation values vary within its coma, which is the cloud of gas and dust surrounding the comet's nucleus. This means that different parts of the coma have different dust properties. Overall, it was concluded that the comet 156P/Russell-LINEAR is very similar to another Jupiter family comet, 67P/ChuryumovGerasimenko. While we still have much to learn about this comet, this study has given us some important clues about the behavior and makeup of a comet that has never been studied previously.
- A transiting massive giant planet has been discovered around a subgiant F-type star TOI-4603, in $7.24599^{+0.00022}_{-0.00021}$ days orbit using the PARAS spectrograph. This is the third exoplanet discovery with PARAS. TOI-4603b has a mass of $12.89^{+0.58}_{-0.57}$ $\mathrm{M_J}$ and a radius of $1.042^{+0.038}_{-0.035}$ $\mathrm{R_J}$, which results in the density of $14.1^{+1.7}_{-1.6}$ g cm^{-3}. This makes it the densest exoplanet among the zoo of exoplanets known to this date and lies in the transition mass region of massive giant planets and low-mass brown dwarfs, an important addition to the population of less than five objects in this mass range. The eccentricity of 0.325 0.020 and an orbital separation of 0.0888 0.0010 AU from its host star, suggests that the planet is likely undergoing high eccentricity tidal (HET) migration. We find a fraction of heavy elements of $0.13^{+0.05}_{-0.06}$ and metal enrichment of the planet ($\mathrm{Z_P}/\mathrm{Z}_{star}$) of $4.2^{+1.6}_{-2.0}$. Detection of such systems will offer us to gain valuable insights into the governing mechanisms of massive planets and improve our understanding of their dominant formation and migration mechanisms.
- Dust and molecular filaments are actively involved in star formation processes (including massive OB stars ($\mathrm{M} > 8\ \mathrm{M}_{\odot}$). There are two popular scenarios when it comes to the role of filaments in star formation. One is called the End-Dominated Collapse scenario, where isolated filaments collapse faster at their ends due to high gas acceleration. However, the observational examples of this case are very limited in the literature. In another scenario concerning the "Hub- Filament System", multiple filaments converge at a common place (i.e., central-hub), that gain sufficient mass and density to form

massive stars. The simultaneous existence or connection of these processes is not well understood. In this relation, a nearby (distance $\sim$ 600 pc) and popular massive star-forming filament, IC 5146 dark Streamer has been observationally studied. High- resolution column density map of the IC 5146 region revealed the presence of at least two intertwined sub-filaments. Observationally, such structures in molecular filaments are very rare. High-column density regions are traced at the edges of the main filament, where hub-filament systems were found in previous studies. Using the molecular line data, the existence of two cloud components around 2 and 5 km/s towards the main filament is investigated. Overall, the interaction between these cloud components might have formed the observed hub-filament systems at the filament edges. Altogether, the IC 5146 Streamer can be recognized as the first reliable candidate of multiple processes of edge collapse, hub-filament systems, and intertwined sub-filaments together.

- In recent years, infrared and sub-millimeter data have revealed a wealth of bubbles and filamentary structures in star-forming regions, which are often associated with star-forming clumps, clusters of protostars, and massive stars (M $>$ 8 $M_{\odot}$). Understanding the role of filaments in the formation of dense star-forming clumps and the feedback of massive stars in their vicinity is still an open research topic in the area of star formation. In this context, numerous research studies on dust and molecular filaments have been conducted in star-forming sites, but only a limited number of studies have focused on ionized filaments. Ionized filaments traced by radio continuum maps may contain a series of ionized compact clumps excited by massive stars, supporting ongoing massive star formation activities. Hence, such targets offer to study not only the birth of massive stars but also the origin of ionized filaments. In this relation, a multi-wavelength and multi-scale study of a wide area hosting massive star-forming regions around l = 345.5 degree is performed. This study reveals the ionized, dust, and molecular filaments in the target area. The analysis of the near- and mid-infrared photometric data depicts noticeable protostars toward the filaments. The findings show the presence of networks of dust filaments associated with massive stars and clusters of protostars, and signatures of interacting molecular filaments. The existence of the ionized filaments seems to be explained by the combined feedback of massive stars. The molecular filaments favour the outcomes of the most recent model concerning the escape and the trapping of the ionizing radiation from an O-type star formed in a filament.
- An in-depth study of a large and long duration ($>$1.3 d) X-ray flare, observed on an RS CVn-type eclipsing binary system SZ Psc was carried out by using data from Swift observations. In the 0.35-10 keV range, the peak luminosity is estimated to be 4.2 $\times$ 10^{33} erg/s. The quiescent corona of SZ Psc was observed about 5.67 days after the flare using Swift observatory, and also about 1.4 yr after the flare using the XMM-Newton satellite. The quiescent corona is found to consist of three temperature plasma: 4, 13, and 48 Million Kelvin. High-resolution X-ray spectral analysis of the quiescent corona of SZ Psc suggests that the high first ionization potential (FIP) elements are more abundant than the low-FIP elements. The time-resolved X-ray spectroscopy shows a significant variation in the flare temperature, emission measure, and abundance. Using the hydrodynamic loop modeling, we derive the loop length of the flare as 6.3 $\times$ 10^{11} cm, whereas the loop pressure and density at the flare peak are derived to be 3.5 $\times$ 10^{3} dyn cm^{-2} and 8 $\times$ 10^{10} cm^{-3}, respectively. The total magnetic field to produce the flare is estimated to be 490 G. The large magnetic field at the coronal height is supposed to be due to the presence of an extended convection zone of the subgiant and the high orbital velocity.
- A detailed study of optical and X-ray properties of Be/X-ray binary pulsar 1A 0535+262 during its recent giant X-ray outburst was carried out by using data from PRL's 1.2 m telescope at Mnt. Abu and AstroSat. The observed prominent Hα line in the optical spectrum is found to be significantly variable. The single-peaked Hα line appeared asymmetric with broad red- & blue wings before and during the outburst. The post-outburst observations, however, resulted in a double-peaked profile with asymmetry in the blue wing. Our analysis revealed that the circumstellar disc around the Be star is highly misaligned. The torque applied by the neutron star on the disc during the periastron passage, causes the disc to precess. As the disc is not a solid object, rings of matter in the disc precess at different rates, which causes the warping of the disc. Our study suggests that the presence of a warped circumstellar disc around the Be star is the cause of giant X-ray outburst in the Be/X-ray binaries.
- Broad-band X-ray spectral study of the persistent Galactic black hole X-ray binary GRS 1758-258 was carried out by using simultaneous observations of the source with Swift and NuSTAR observatories. Broad-band spectral fitting with an absorbed power-law model revealed the presence of a broad Iron (Fe) emission line and reflection hump in the spectrum. We used different flavors of the relativistic reflection model for the spectral analysis. All models indicate the spin of the black hole in GRS 1758-258 is greater than 0.92. The source was in the low hard state during the observation, with the hot electron temperature of the corona estimated to be 140 keV. The black hole is found to be accreting at $\sim$ 1.5% of the Eddington limit during the observation, assuming the black hole mass of 10 solar mass and distance of 8 kpc.
- Detailed X-ray spectroscopic analysis of observations of a black hole binary MAXI J1631–479 made by two international X-ray observatories, namely NuSTAR and NICER, showed a very interesting result that a black hole harbored by this binary system is likely to be the heaviest stellar mass black hole in our galaxy. The most likely mass of the black hole in this X-ray binary is in the range of 30 to 60 solar mass. This result is significant in light of the apparent dichotomy arising from the recent detection of the stellar mass black holes using an independent technique of gravitational wave (GW) detection.
- Timing and spectral studies of the highly obscured low luminosity active galactic nucleus NGC 4941 was carried out by using data from the nuclear spectroscopic telescope array and the Neil Gehrels Swift observatories. The variabilities in 3-10 keV and 10-60 keV energy ranges are found to be similar with fractional rms variability of $\sim$ 14%. The broad-band spectral properties of the source were investigated in 3-150 keV range, using data from NuSTAR and Swift/BAT, with phenomenological slab model and physically motivated MYTORUS model. From the spectral analysis, heavy obscuration was found with a global average column density of the obscured material as 3.09 $\times$ $10^{24}$$cm^{-2}$. Evidence of a strong reflection component is observed in the spectrum. A

strong iron line with an equivalent width of $\sim$ 1 keV is detected in the spectrum. From the slab model, the exponential cutoff energy was estimated to be 177 keV. From this, we estimate the Compton cloud properties with the hot electron temperature of 59 keV and the optical depth τ =2 .7.

- AstroSat observation of the black hole candidate MAXI J1803-298 on 2021 May 11-12, revealed the presence of four periodic absorption dips with a periodicity of 7.02 hours in the light curve. AstroSat observed the source when it was undergoing a transition from hard-intermediate state to soft-intermediate state. Our timing analysis reveals the presence of a sharp Type-C quasi-periodic oscillation (QPO) in the power-density spectra (PDS) with an evolving QPO frequency ranging from 5.31 to 7.61 Hz. The combined 0.7-80 keV SXT and LAXPC spectra are fitted with a model consisting of thermal multi-colour blackbody emission and Comptonized emission components. Time-resolved spectroscopy during the dip and non-dip phases of the observation, revealed the presence of a neutral absorber during the dip and non-dip phases though a signature of an ionized absorber is also present in the dip phases. The spectral and temporal parameters are found to evolve during our observation. We estimate the mass function of the system as f(M) = 2.1 - 7.2 solar mass and the mass of the black hole candidate in the range of 3.5 - 12.5 solar mass.
- Astronomers discover 'Elusive Dying Radio Galaxies' using deep radio surveys Dying or remnant, radio galaxies represent the final stage in a radio galaxy's life-cycle and are considered elusive because they spend a relatively short time in this phase. Radio galaxies are powered by Active Galactic Nuclei (AGN), and once AGN activity stops, the jets are no longer supported but the lobes of plasma created by the jet activity can still be detected before they disappear due to radiative losses. To detect dying radio galaxies, we used deep multi-frequency radio surveys performed with the GMRT in India, the low frequency array (LOFAR) telescope in the Netherlands, and the very large array (VLA) in the USA. By studying the images and spectra of a large number of radio galaxies, we were able to identify nearly two dozen radio galaxies that showed relic emission from lobes with no AGN activity. These dying galaxies were searched for within a small sky area of 12 square degrees in the XMM-Newton Large Scale Structure (XMM-LSS) extragalactic field. The discovery will help us to understand the factors that govern the evolution of radio galaxies in their final phase and assess the amount of energy that these dying sources feed back into their host galaxies and the intergalactic medium.

Solar Physics

- The multipolar complex magnetic regions on the Sun are highly susceptible to produce energetic events in the form of flares, CMEs etc. Observations suggest that the initiation of large-scale solar eruptions is usually linked to small-scale magnetic complexities at the source region. It is now widely believed that the early dynamics of a CME necessarily depends on the embedded flux rope system, which acts as a central driver of the CME formation process and its subsequent eruptive acceleration. However, it still remains unclear how the CME develops in the low corona and evolves into a large-scale structure during its subsequent phases. With this motivation, a study was conducted which was comprised of three homologous compact major blowout-eruption solar flares. The sequential eruption of flux rope system led to the homologous flares, each followed by a CME, which gradually attained large angular width in the outer corona. In this context, a generalized Magnetic-Arch-Blowout (MAB) scanerio explains the underlying physics of formation of broad CMEs resulting from compact eruption-source site, providing useful inputs toward the near-Earth space-weather prediction.

Space and Atmospheric Sciences

- Contributions of natural and anthropogenic sources of volatile organic compounds (VOCs) vary on local and regional scales. In recent years, emission from the use of fossil fuels is the main anthropogenic source of ambient air VOCs in the urban regions of developing countries. Other sources such as biomass/biofuel burning and biogenic emissions also influence urban air quality in tropical regions. The distinction between biogenic and anthropogenic contributions of VOCs in urban air is not straightforward because many VOCs are emitted from several co-located sources. In this study, we performed simultaneous VOC measurements using state-of-art instruments at the urban and suburban sites of New Delhi in the polluted Indo-Gangetic Plains of India during the winter season. Besides the impact of primary sources, we have also investigated the roles of photochemical secondary formation of oxygenated VOCs. Our findings will help policymakers develop strategies for controlling primary and secondary pollutants in this tropical urban region. This is a most comprehensive study investigating the importance of VOC composition in air quality and atmospheric chemistry in New Delhi. In detail, we have investigated vehicular exhaust, episodes of biomass burning, biogenic emissions and photochemistry influencing the levels of primary and secondary air pollutants (Air quality) and Atmospheric chemistry using both observation and model in New Delhi.
- The Atmospheric Boundary Layer (ABL) is the lowermost layer of the atmosphere in contact with the Earth's surface and acts as a packing volume of the atmospheric pollutants. The national lockdown in India provided a unique opportunity to study the effects of reduced anthropogenic emissions; it was a blessing in disguise for the healing process of our atmosphere. Due to drastic changes in emissions, the Ahmedabad region showed improved air quality with a significant reduction in surface particulate matter concentrations. It was found that the BLH was reduced during the lockdown period. These observations were made using a ground-based ceilometer lidar and corroborated by ERA5 reanalysis data. The reduction in the boundary layer was correlated with the increased rain events due to the western disturbances during the same period. In hindsight, it can be linked with the reduction in anthropogenic emissions. Thus, this study can be referred to for future policy making decisions in trying to reduce the pollution index of the region. It has been observed that complete isolation of anthropogenic activity can substantially improve atmospheric conditions.
- A close examination, for the first time, using high-quality, two-decade long ground-based and satellite observations since 2001 of aerosols and their radiative effects from several locations in the Indo-Gangetic Plain in South Asia and the

North China Plain in East Asia, revealed a clear divergence in the trends in aerosol optical depth (AOD). The single scattering albedo (SSA) is increasing, and the absorption AOD due to carbonaceous aerosols is decreasing over both the regions, confirming that aerosols are becoming more scattering in nature over Asia. Aerosols in fine mode have increased (trends are statistically significant) whereas coarse mode natural aerosols have declined, which are attributed mainly to changes in anthropogenic aerosol emissions, and not to natural and climatic factors as their changes are relatively small. These findings on hitherto unavailable climatology and trends in aerosols and absorbing aerosols over two global aerosol hotspots and identified contrasts will be crucial in model simulations to better decipher aerosol-climate interactions over Asia.

- A comprehensive year-round analysis of black carbon (BC) mass concentration and its source apportionment during the nationwide lockdown imposed due to the Coronavirus Disease 2019 (COVID-19) revealed that BC mass concentration decreased by 35% during the lockdown. The contribution due to biomass (wood fuel) burning to BC was higher due to an increase in the biomass burning emissions from the several community kitchens which were operational during the lockdown. The quantitative findings from the present study on BC during the unprecedented COVID-19 induced lockdown can provide a comprehensive understanding of the BC sources and current emission control strategies, and can serve as baseline anthropogenic emissions scenarios for future emission control strategies aimed to improve air quality and climate.
- An analysis of high-quality ground-based observations and two spatially resolved model simulations of physical, optical and chemical characteristics of aerosols over the Indo-Gangetic Plain revealed significant differences between models and observations, and model to model differences. A classification of aerosol types and absorbing aerosol types on a seasonal scale over the Indo-Gangetic Plain (IGP) revealed that biomass burning, urban-industrial and mixed aerosol types are present throughout the year over the IGP whereas dust is present only during pre-monsoon and monsoon. A regional-scale examination further emphasized that the atmospheric warming due to black carbon is higher over South Asia due to its higher aerosol optical depth and absorbing efficiency. This quantification of absorbing aerosol types over a global aerosol hotspot will help improve aerosol processes and parameterizations in models and will enable an accurate quantification of climate impacts of aerosols.
- Using Krassovsky's method we have investigated terdiurnal, large- and small-timescale gravity wave characteristics using nocturnal variations of the OH(3-1) brightness and its rotational temperatures measured with PRL Airglow InfraRed Spectrograph (PAIRS). Using single altitude observations amplitudes, phases, Krassovsky parameters, and vertical wavelengths of the terdiurnal tide and GWs were derived. Owing to high data cadence of PAIRS, GW characteristics with periodicities smaller than 30 minutes were obtained that showed vertical propagation in the MLT region. This study demonstrates that the dynamics of the MLT region are influenced by upward propagating waves having different wave characteristics which are present at different times throughout the night.
- Tidal dynamics during a minor but impactful sudden stratospheric warming in the southern hemisphere revealed a few interesting features. A handful of global modes show clear response to the warming event unlike the local tidal activity. Although the seasonal tidal variability seems to be driven by the dominant atmospheric sources, the warming associated with small scale variations in the tidal modes do not reveal any clear relationship with the plausible sources indicating involvement of complex dynamical processes.
- By employing a new radio based approach of deriving vertical propagation characteristics of gravity waves in daytime thermosphere, PRL scientists have shown that whenever the vertical speeds of the gravity waves are greater than 80 ms^{-1} the plasma irregularities were most likely to occur. As the vertical propagations are obtained during 10-14 LT, the occurrence of gravity wave can be predicted well in advance, which is by far the best ever reported.
- By employing combined optical and radio measurements innovatively, PRL scientists have derived the gravity wave characteristics in the daytime in 3-D for the first time. These measurements were obtained by large field of view dayglow emissions and digisonde measurements from Ahmedabad. Not only were the gravity wave time periods, scale sizes and propagation speeds in all the directions obtained, but also daytime neutral winds were inferred using the measured values of gravity waves in three dimensions in the gravity wave dispersion relation. These are first results on obtaining the daytime thermospheric neutral winds from ground-based observations.
- All-sky images at OI 630 nm emissions were obtained from an off-equatorial location, Kolhapur. Zonal wavenumber analysis has been carried out on about 1300 images, which showed scale sizes in the range of 250 - 300 km during times of no plasma bubbles. But during the times of bubbles the scales were shorter – 50 - 250 km. Also the bubbles drift eastwards with speeds of 130 - 90 ms^{-1}. It is inferred that shorter scale size gravity waves play a significant role in seeding the perturbation of the EPBs.
- Despite helium abundance [A_{He} = (n_{He}/n_H) $\times$ 100] being $\sim$8 percent at the solar photospheric/chromospheric heights, A_{He} can be found to exceed 8 percent in interplanetary coronal mass ejections (ICMEs) on many occasions. None of the proposed processes could explain the variability of A_{He} in ICMEs comprehensively so far. Based on an extensive analysis, we show that chromospheric evaporation in tandem with gravitational settling determines the A_{He} enhancements and variabilities beyond 8 percent in ICMEs. While chromospheric evaporation releases the helium from the chromosphere into the corona, the gravitationally settled helium is thrown out during the ICMEs. We show that the intensity and timing of the preceding flares from the same active region from where the CME erupts are important factors to understand the A_{He} enhancements in ICMEs.
- Investigations on the solar cycle variation of the properties of suprathermal populations (H and other heavy ions like ^{4}He, ^{3}He, C, O, and Fe) in the solar wind are sparse and hence poorly understood. In this work, we show significant differences in the spectral indices between ^{4}He and Fe in cycle 24 compared to cycle 23. These results suggest that generation mechanisms responsible for suprathermal ^{4}He and Fe underwent changes in cycle 24 and these mechanisms

are probably dependent on the first ionization potential and mass-to-charge ratio.

- During a minor geomagnetic storm, penetration electric field perturbations over the Indian dip equatorial sector are found to be anomalous on a number of occasions during post-sunset hours. It is shown that the anomalous penetration electric field perturbation on one occasion during this event arises from the effects of the Y-component of the interplanetary magnetic field (IMF B_y). During another geomagnetic storm, we also show global asymmetry in the ΔX (X- northward component of geomagnetic field) variations between nearly antipodal stations from the Japanese-European/African sector with respect to the same between the nearly antipodal stations from the Pacific/American-Indian sector. This asymmetry is observed during the period when the absolute magnitude of IMF B_y is larger than that of IMF B_z resulting in a significant and conspicuous enhancement in IMF $|B_y/B_z|$. These results bring out the poorly understood effects of IMF B_y on equatorial ionospheric electrodynamics.

Planetary Sciences

- Fundamental changes in thermal and mantle melting regime in the Moon through time have been observed. The studied lunar meteorites (3.9-4.35 Ga) were sourced from a cool, shallow, and compositionally distinct part of the lunar mantle. The study explored the possible mechanisms through which these KREEP-free lunar basalts might have been formed. Importantly, the calculation indicates that the energy generated by radioactive materials alone cannot be a major driving force for the lunar magmatism, especially for the KREEP-free lunar rocks formation. Instead, these ancient KREEP-free lunar basalts might have been formed from low-pressure decompression melting in the Moon. The study presents the complexities in lunar mantle and questions the traditional idea of mantle overturn.
- A meteorite has fallen at Diyodar Taluka, Banaskantha district, Gujarat on 17th August, 2022. A group of PRL scientists visited the fall areas and collected two fragments ($\sim$200 g and $\sim$20 g) from the Tehsildar office at Diyodar on 23^{rd} August, 2022. The sample is a stony achondrite breccia with a predominant constituent of white pyroxene grains of various size and shape. The dominant mineral phase is enstatitic pyroxene, while diopsidic pyroxene is also present as the next dominant phase. Olivine is forsteritic, and plagioclase is albitic. The sample contains various sulfides. Preliminary description and study suggest that the meteorite is a rare, unique specimen of Aubrite.
- The production rates of different metallic species, generated due to dust ablation on Mars and Venus are presented. The new velocity distributions of particles at Mars and Venus are shown using Galileo observations of interplanetary dust. For the first time, the effects of atmospheric and dust parameters as well as uncertainties involved therein, are considered at one place for Mars. A new interplanetary dust flux model is proposed for Venus, based on the available observations.
- A power law model is suggested for the flux of interplanetary dust at Earth. An upper limit of dust density around Earth is found to be 10^{-4} #/m^3, on an average. SIMION results give first-hand estimate of plasma capture efficiency of dust detector for an optimum bias. ACE, GOES and SPENVIS data are analyzed to estimate the background noise in space. Geant4 results show the presence of background noise in electron channel only. The signal coincidence can uniquely identify a dust impact in the presence of noise.
- The characterization of ice embedded in regolith materials and modelling to evaluate the real component of electric permittivity for the lunar subsurface has been performed. The frequency dependence of the real component of the electric permittivity is determined at temperatures 190 and 220 K, over a frequency range 1 Hz to 1 kHz for pure ice. The electric permittivity of two-component icerock mixtures is calculated for various ice concentrations.
- Plasma and magnetic field data obtained from 627 orbits of Mars Atmosphere and Volatile Evolution (MAVEN) that occurred during October 2014, April 2015, September 2017 and May 2018, when the spacecraft was crossing the magnetic pile-up boundary of Mars, have been analysed. A steep ionopause-like boundary is observed in 24 profiles of 627 orbits, when MAVEN was passing from the magnetic pile-up region during the daytime ionosphere in presence of horizontal magnetic field of high strength, while their night side ionosphere did not show such boundary in presence of horizontal magnetic field of low strength. These profiles are unique, which have not been reported earlier. It is proposed that the horizontal magnetic field can form such ionopause within the magnetic pile-up boundary during the daytime if time and location of the magnetic anomaly coincide with the ion and electron density measurements.
- Lunar swirls are high-albedo irregular markings that are generally associated with prominent magnetic anomalies. The formation of swirls is still unknown. We provided detailed physical characteristics of the regolith at the Reiner Gamma swirl by using the first time systematic telescopic observations obtained at the Mount Abu IR Observatory between January and March, 2021. A comparison of the polarization properties of Reiner Gamma swirl with the craters Kepler and Aristarchus suggested grain size variations within the swirl structure. The Hapke modeling of the Reiner Gamma swirl suggested significant changes in the opposition effect strength at the central oval, but only marginal differences in surface roughness from its surroundings. These results confirm the occurrence of surface alteration processes that might have disrupted the regolith microstructure in the Reiner Gamma swirl. These findings are consistent with an external mechanism of swirl formation, by considering interaction between the regolith and cometary gas. Subsequent to its formation, the swirl structure was preserved due to shielding by crustal magnetic field.
- A compositionally distinct new unit basaltic unit "Margins West" has been discovered in the Mare Marginis (13.3°N, 86.1°E) and Mare Smythii (13.3°N, 86.1°E) region on the basis of detailed compositional investigation of the basalts using data from Moon Mineralogy Mapper (M3), Chandrayaan-1 have led to the discovery of in the region. The compositional variability in the region and age data suggest that both Crisium and Smythii Basins influenced the volcanism in Mare Marginis. Thus, the pre-existing structures in the lunar crust generated by large-scale impacts play an important role in the volcanism on the Moon.
- A total of 23 potential caves have been discovered in the Elysium Mons region of Mars on the basis of morphology,

geological context, and thermal behaviour of the region determined from CTX, HiRISE, MOLA, and THEMIS data. Further, cave entrance has been detected in nine candidates. These sites could be important destinations for future robotic/human exploration and the search for life on Mars.

- It is not well known how the Martian gullies formed on bedrock and/or lithified sediments would currently evolve, and this forms the basis for investigation of 1483 craters with ∼10,000 gullies to find out a connection between gullies that currently change and those that do not due to the CO_2 ice sublimation. CO_2 ice related processes are able to erode both sand-filled gully channels and dune gully channels to form linear channels with terminal pits. In contrast, gullies formed on the bedrock and glacial substrate do not show a change indicating that they may not be able to be eroded by CO_2 ice processes in a manner similar to the loose, unconsolidated substrate in sand-filled gully channels investigated in this study. Therefore, the study signifies that the sand-filled gully channels represent a significant component of present-day modification of gully channels on Mars.
- Cosmic ray exposure history of several meteorites fell in India as well as from elsewhere of type ordinary chondrites were carried out using cosmogenic neon isotope. The exposure age of some meteorites fell on the major peaks in the histogram. This indicates that they are the representative of major impact event occurred in their parent body.
- The M3 layer is a local enhancement in the electron density above the prominent ionospheric M2 peak on Mars. An analysis of 179 dayside electron density profiles from July 2016 to December 2020, provided by the Radio Occultation Science Experiment (ROSE) onboard MAVEN, show a typical altitude of M3 layer as 180 km, with a density of 8000 cm^{-3}. The results are consistent with those reported from MGS RO data. In the northern hemisphere, both the M3 peak density and altitude seem insensitive to latitudinal changes. It was found that the presence of crustal magnetic field could not wholly explain the formation of M3 layer.

Geosciences

- Black carbon concentrations and its isotopic compositions in a sediment core retrieved from the Wular Lake (Jammu and Kashmir) revealed precipitation and fire history in the region for the past 4000 yrs. The study revealed two distinct climatic phases in the region characterised by a dry phase during 3750–1500 cal year BP (Before Present) and a wet phase during 1500–300 cal year BP. These results, in combination with available studies from the region, suggested that forest fires in the Kashmir Himalaya during the study period were dominantly human-driven rather than that caused by large scale climate change.
- A stalagmite from Belum cave (Kurnool district, Andhra Pradesh) was used to retrieve past signatures of monsoon fluctuations from ∼183 ka to ∼175 ka and ∼104 ka to ∼82 ka. Variability in stable oxygen and carbon isotope compositions and trace element concentrations shows that processes occurring in the southern hemisphere on millennium time scale affect the Indian monsoon strength. The cross-equatorial flow of moisture, caused by atmospheric pressure gradient is a possible process that sends climate signals from the southern hemisphere to the northern hemisphere.
- October–November months are known for large paddy-residue burning (PRB) over the north-western Indo-Gangetic Plain (IGP). Characterization of PRB derived carbonaceous aerosols using dual carbon isotopes (^{13}C and ^{14}C) highlights that about 82% of carbonaceous aerosols are PRB derived and their average $\delta^{13}C$ value is -28.9 $\pm$ 1.1 ‰during the PRB months. Such studies including tracking the PRB derived fractions in the downwind regions are crucial in assessing the effects of PRB on regional air quality and climate.
- Oxidative potential (OP) of aerosols was studied over Shillong. Results suggest that the OP of aerosols (mainly organics) increases with their aging. It implicates that toxicants emitted over a source region (such as from biomass burning emissions in northern India) become more toxic during the long-range transport, as observed over Shillong.
- Dark carbon (C) fixation in the ocean twilight zone plays a crucial role toward C sink, but its potential has not been tested sufficiently with experiments. We found that the dark C fixation rates to the global ocean ranged up to 7.4 Pg C y^{-1}; amounting to ∼15% of the global ocean primary production.
- A key assumption in the application of stable molybdenum (Mo) isotopes (δ^{98}Mo) in tracking past ocean redox state is that the isotopic composition of the dissolved Mo supply to the oceans has remained constant through the geological history of the earth. This hypothesis was tested by measuring water samples from the Narmada River. The δ^{98}Mo of the Narmada River water varies significantly, from 0.30 to 0.92 ‰, and is heavier than the crustal components, showing significant control of continental weathering, soil organic matter cycling, secondary mineral formation, and surface-ground water interactions.
- Sustainable water flow in the Ganga, one of the largest rivers in the world in size and discharge, is very important as it supports the livelihood of more than 400 million population. A detailed stable isotope based analysis depicted that the summer season evaporative loss was ∼58% of the Ganga water in its middle plain segment (length ∼1200 km) in 2019. Also an increase of ∼120% of water near the end of the middle segment compared to that started at the beginning of the segment due to groundwater discharge was estimated. Our field observation and in situ groundwater data indicate that the recent decrease in Ganga water flow in summer was due to artificial diversions, decrease in inflow from tributaries and increased human interventions.
- Carbonate clumped isotope (Δ47) in three near surface dwelling planktic foraminifera in a sediment core collected from the South China Sea revealed an overall SST increase of 9 $\pm$3 $^{\circ}$C from the Last Glacial Maximum (LGM) to Holocene in the region. This large change in SST was explained by combined effects of changing air temperature and oceanic upwelling. Enhanced upwelling during the LGM was supported by the abundance of upwelling indicator diatom species.
- Estimation of residence times of groundwater, particularly in regions with inadequate surface waters are very important for formulating sustainable groundwater management policies. Using a newly developed technique for measuring ^{14}C contents in groundwater dissolved inorganic carbon (DIC), its residence time is estimated employing Lumped Parameter Models (LPM), a set of mathematical models that take care of the ^{14}C

variation in DIC due to subsurface processes. The residence times of groundwater of Ahmedabad used for household and industrial activity varies substantially from place to place. For example, groundwater residence times of PRL campuses at Navrangpura and Thaltej are 3300 and 5000 yrs, respectively.

- The eastern side of the Indian Ocean is an important region which connects the Pacific Ocean to the Indian Ocean through the Indonesian throughflow (ITF). Along with the transport of heat and water mass, the ITF also plays an important role in the distribution of tracers such as radiocarbon in the ocean. Coral radiocarbon records from Cocos Islands provide a good opportunity to understand the influence of ITF on the radiocarbon levels of the surface seawater in the south-eastern tropical Indian Ocean. Our data and model results showed that apart from the atmosphere, lateral input via the ITF also contributed bomb radiocarbon to the surface seawater near the Cocos Islands.

- The radioactive ^{10}Be input to the ocean varies spatially depending on the troposphere-stratosphere exchange, variation in precipitation rate, and variability in aerosol content but ^{9}Be is predominantly of terrestrial origin. ^{9}Be in rivers is dominated by continental runoff and is mostly scavenged within the estuarine and coastal regions, and hence its input to the open ocean is minimal. A detailed investigation with Be isotopic measurements in surface sediments in the central and the northern Indian Ocean showed that the Bay of Bengal, with an enhanced supply of terrestrial material, has a higher ^{9}Be concentration and lower ^{10}Be/^{9}Be ratio. Whereas, the central Indian Ocean has a higher ^{10}Be/^{9}Be ratio due to no direct terrestrial source. Scavenging by sediment particles plays a vital role in the distribution of Be isotopes in well-mixed open ocean water.

- High-resolution radiocarbon records from corals provide essential insight on ocean circulation, upwelling and the air-sea CO_2 exchange process from different ocean basins. The sub-annually resolved radiocarbon and stable oxygen isotope record of a coral from the Andaman Sea in the northern Indian Ocean showed that the seasonal variation in the radiocarbon content was superimposed over a secular decreasing trend of about 2.7‰yr^{-1}. The coral Δ^{14}C values show that the Andaman Sea surface waters have also become more enriched in radiocarbon compared to the atmosphere in the last decade.

- The Indian Summer Monsoon (ISM) and the mid-latitude westerlies are the two major sources of moisture feeding the Himalayan glaciers. Well-preserved relict proglacial lacustrine sequences from the cold and arid northwest Ladakh Himalaya, is used to reconstruct the late Quaternary climate variability using geochemical proxies. We observed an enhanced moisture during mid MIS-2 and was found to be contributed by the mid-latitude westerlies, with a subordinate contribution from the Indian Summer Monsoon (ISM). The Indus basin responded to the coupled synoptic-scale climate system, which in the present case were the fluctuations in the valley glaciers modulated by the changing strength of the mid-latitude westerlies caused due to the winnowing and waxing of the northern latitude ice dynamic.

Atomic, Molecular and Optical Physics

- Explored a new Post Violet Infrared Luminescence (PVIR) signal which has zero fading and useful for luminescence dating using feldspar. The signal has higher saturation dose compared to conventional luminescence signals.
- Dated middle Palaeolithic artefact to $>$247 32 ka implying that South Asian Middle Palaeolithic assemblages could be part of local innovation that emerged from older Acheulian technologies. This establishes the tool technology in India is quite old as expected till date.
- Utilizing asymmetry of the pump beam produced anisotropic spatial entanglement and also demonstrated death of the entanglement. The results will find applications in quantum sensing and quantum imaging.
- Verified entanglement duality for polarization and orbital angular momentum experimentally using indistinguishable photons. It will find applications in robust quantum communication, remote entanglement generation and distributed quantum sensing.
- Our results on quantum key distribution (QKD) through the atmosphere show that the concentration and extinction coefficient of atmospheric aerosols play a major role in influencing the key rate in QKD. Such experiments are important to validate the models to account for the atmospheric effects on the key rates achieved through satellite-based QKD.
- Presented a speckle-based deep learning approach for orbital angular momentum (OAM) mode classification. The results will be utilized in increasing the information capacity of the communication channel using OAM modes.
- Presented a Physically Unclonable Function (PUF) to produce a robust encryption key for the digital implementation of any optical encoding system by utilizing correlation functions of the scattered perfect optical vortex (POV) beams
- Plume expansion dynamics have been studied in the case of nanoparticle enhanced laser produced plasma (NELPP) in different ambient and laser fluences. Study of confining liquid on nanoparticles synthesized by laser ablation in liquid was carried out.
- Laser produced underwater dynamics were studied using two investigation techniques viz., shadowgraphy and optical beam deflection. Role of plasma temperature and electron number density on signal enhancement observed in nanoparticle enhanced LIBS was investigated.
- Our understanding on the role of amorphous carbon in the interstellar medium to form complex structures, such as carbon nanotube/graphene/fullerene, is limited to date. We have investigated how shocks may induce physico-chemical transformation in amorphous carbon by subjecting samples of carbon nanopowder to high-temperature shocks, $\sim$7300 K, in a hydrogen-free environment for about 2 ms using a shock tube. The shock conditions achieved in the laboratory mimics low velocity interstellar shocks. Post shock samples were analyzed using Raman Spectroscopy and High Resolution Transmission Electron Microscopy. We have found compelling evidence for the formation of carbon nanotube, graphene, and various other carbon nanostructures induced by the shock. Our results show that shocks in the interstellar medium can provide important chemical pathways to the formation of fullerenes and suggests that other carbonaceous structures may be present as well.

- Many icy bodies in the solar system have been found to contain a rich mixture of simple molecules on their surfaces. Similarly, comets are now known to be a reservoir of molecules ranging from water to amides. The processing of planetary/cometary ices leads to the synthesis of more complex molecules some of which may be the harbingers of life. Carbon disulphide (CS_2) and ammonia (NH_3) are known to be present on many icy satellites and comets. Reactions involving CS_2 and NH_3 may lead to the formation of larger molecules that are stable under space conditions. In this paper, we present temperature-dependent VUV spectra of pure CS_2 in the ice phase, and of CS_2 and NH_3 ices deposited as (i) layered, and (ii) mixed ices at 10K and warmed to higher temperatures until their sublimation. Pure CS_2 ice is found to have a broad absorption in the VUV region, which is unique for a small molecule in the ice phase. In layered and mixed ices, the molecules tend to affect the phase change and sublimation temperature of each other and also leave behind a form of CS_2-NH_3complex after thermal annealing. This study of CS_2-NH_3 ice systems in layered and mixed configurations would support the detection of these species/complexes in mixed molecular ices analogous to that on planetary and cometary surfaces.
- Impact delivery of prebiotic compounds to the early Earth from an impacting comet is considered to be one of the possible ways by which prebiotic molecules arrived on the Earth. Given the ubiquity of impact features observed on all planetary bodies, bolide impacts may be a common source of organics on other planetary bodies both in our own and other solar systems. Biomolecules such as amino acids have been detected on comets and are known to be synthesized due to impact-induced shock processing. Here we report the results of a set of hypervelocity impact experiments where we shocked icy mixtures of amino acids mimicking the icy surface of planetary bodies with high-speed projectiles using a two-stage light gas gun and analyzed the ejecta material after impact. Electron microscopic observations of the ejecta have shown the presence of macroscale structures with long polypeptide chains revealed from LCMS analysis. These results suggest a pathway in which impact on cometary ices containing building blocks of life can lead to the synthesis of material architectures that could have played a role in the emergence of life on the Earth and which may be applied to other planetary bodies as well.
- Quantum control of the molecular photodissociative reaction is studied using two-color photoionization of N_2 and CO. The yield of the parent ion and its charged fragments as a function of the phase difference between the two-color field has been investigated. It observed that the ionized N_2 and CO with their fragments have different correlation trends at different polarization schemes. We demonstrated the Quantum control of molecular reaction using a two-color photoionization scheme
- Femtosecond laser pulses induced strong-field ionization of CH_3Cl is studied using an in-house developed Cold Target Recoil Ion Momentum Spectrometer (COLTRIMS) setup. We identified four two-body breakup pathways of CH_3Cl^{2+}. We observed that the yields of two-body pathways decrease by increasing the intensity from I = 4.2 10^{13} W cm^{-2} to 2I = 8.5 10^{13} W cm^{-2}, which was attributed to enhanced ionization of the dication before it can dissociate.
- A crucial step towards realization of Quantum Computing in the context of many-electron systems requires a rigorous quantum mechanicaltreatment of dierent interactions. We have carried out a pilot study to investigate the physical eects beyond the mean-eld approximation, known as electron correlations, in the ground state energies of atomic systems using the classical-quantum hybrid variational quantum eigen-solver algorithm. A salient feature of the study involves a detailed analysis to nd the number of shots (the number of times a variational quantum eigensolver algorithm is repeated to build statistics) required for calculations with IBM Qiskits QASM simulator backend, which mimics an ideal quantum computer.
- Electric dipole moments and static electric dipole polarizabilities of the alkali-metalalkaline-earth-metal dimers were analyzed by employing nite-eld coupled-cluster methods in the frameworks of both non- relativistic and four-component spin-free relativistic theories. The behavior of electron correlation eects as well as relativistic eects related to the size of the considered molecules were investigated through this study. In the end, their recommended values were provided for estimating systematic eects in the high-precision spectroscopic measurements involving these molecules
- Precise values of electric polarizabilities for the ground state of Zn due to second-order dipole and quadrupole interactions, and due to third- order dipole-quadrupole interactions were reported. These quantities were evaluated in the linear response theory framework by employing a relativistic version of the normal coupled-cluster method. A machine- learning-based scheme to generate optimized basis functions for atomic calculations was developed and applied here. From the analysis of the dipole polarizability result, accuracy of the calculated quadrupole and third-order polarizability values were ascertained, where experimental values were unavailable.
- Isotope shifts of atomic energy levels are sensitive probes of nuclear structure and new physics beyond the standard model. Analysis of isotope shifts of the cadmium atom and singly charged cadmium ion were carried out rigorously. Combining our calculations for the ion with experiments, atomic parameters for all low-lying transitions in the cadmium atom were inferred. The combination of our precise calculations and measurements showed that King plots for the cadmium atom can improve the state-of-the-art sensitivity to a new heavy boson by up to two orders of magnitude.
- We reported a precise value of nuclear magnetic octupole moment of ^{45}Sc by combining high-precision atomic calculations with measurements of hyperne structure levels in the ground and rst-excited states of the said atom. With a single valence proton outside of a magic calcium core, scandium is ideally suited to test a variety of nuclear models, and to investigate in-depth the many intriguing nuclear structure phenomena observed within the neighbouring isotopes of calcium. We perform nuclear shell-model calculations of nuclear octupole moment and furthermore explore the use of Density Functional Theory for evaluating it. From this, mutually consistent theoretical values of nuclear octupole moment were obtained and found to be in agreement with the experimental value. This conrmed atomic structure calculations possess the accuracy and precision required for magnetic octupole moment measurements.

Theoretical Physics

- Analytical description of propagation of unstable neutrinos in matter is worked out for the first time. The probabilities of conversion of neutrinos from one type to another during such propagation are obtained in compact form for both two and three flavour cases.
- The impact of the mixing angles of the eV scale sterile neutrino on leptogenesis is studied in the context of extended seesaw models. This study correlates mixing angles of the sterile neutrinos with the leptogenesis phenomenon through non-unitarity of the mixing matrix.
- It is pointed out for the first time that extra interactions of neutrinos can help in energy deposition in the gamma ray bursts. From this analysis, constraints were obtained on the corresponding interaction parameters.
- Anomaly detection through machine learning techniques has emerged as a powerful novel tool in searching for new physics beyond the Standard Model of particle physics. Predicting different observables through hadronic-jet-like objects originating from strongly interacting particles at facilities like the Large Hadron Collider requires accurate knowledge of interactions governed by Quantum Chromodynamics (QCD). Akin to the early development phase of these jet observables, this fast development phase of neural network architectures often overlooks to accommodate critical theoretical consistency into consideration. In this context, we construct an infrared and collinear safe autoencoder based on graph neural networks by employing energy-weighted message passing. We demonstrate that whilst this approach has theoretically favourable properties, it also exhibits formidable sensitivity to non-QCD structures.
- Vector boson fusion established itself as a highly reliable channel to probe the Higgs boson and an avenue to uncover new physics at the Large Hadron Collider. This channel provides the most stringent bound on Higgs's invisible decay branching ratio, where the current upper limits are significantly higher than the one expected in the Standard Model. It is remarkable that merely low-level calorimeter data from this characteristically simple process can improve this limit substantially by employing sophisticated deep-learning techniques. Construction of such neural networks seems to comprehend the event kinematics and radiation pattern exceptionally well. However, the full potential of this outstanding capability also warrants a precise theoretical projection of QCD parton showering and corresponding radiation pattern. Our work demonstrates the relation using different recoil schemes in the parton shower with both leading-order and next-to-leading-order approximations.
- We discover various phase transitions in half-Heusler TbPtBi compound using density functional theory. Specifically, inclusion of the spin-orbit coupling (SOC) leads to the band inversion resulting in the transition from the metallic to the topological semimetallic phase. However, in the presence of SOC, there is a phase transition from the topological semimetal to the trivial semimetal when the material is subjected to compressive strain (-7%). Subsequently, under further increase of compressive strain $(\geqslant -7\%)$, we find an opening of a direct band gap at the point, driving the system from the trivial semimetallic to a semiconducting state with changes in the sequence of the bands. These tunable phase transitions (especially as a fraction of strain) make this compound very promising for applications in various quantum devices, such as highly sensitive strain gauges.
- Grand Unified Theories (GUT) which unify the strong, weak and electromagnetic forces predict existence of several spin-less particles and also their interaction strengths with the quarks and leptons. Extensive analysis of SO(10) based GUT has been carried out to investigate the role played by these new particles in the rare processes like nucleon decays, baryon-antibaryon and meson-antimeson oscillations. Results show that the estimated lifetime of some of these processes are quite different from typical expectation based on simplified models and assumptions.
- Properties of ordered matter are set mainly by the symmetry of the ordered state. For superconductivity, the symmetry of Cooper pairs (CPs) plays the major role. Following the symmetry principle, various CPs can exist in superconductors. However, we mostly find s-wave spin-singlet CPs that are well-described by Bardeen-Cooper-Schrieffer (BCS) theory. Several ways have been adopted in the literature to generate non-BCS CPs, but it is always extremely hard to protect any non-BCS CP from being contaminated by BCS and other non-BCS CPs. We have shown how to solve this two-decade old problem in a topological Josephson junction. We are able to generate one of the essential non-BCS CPs (100$\%$) free from any contamination. Our work also offers a highly tunable detection scheme for the same CP.
- Massive experimental efforts have been dedicated at the Large Hadron Collider (LHC) to test the phenomena predicted by the Standard Model of particle physics and remarkable agreements are seen on several occasions. To do such measurements at unprecedented accuracy is an ongoing activity and that requires theoretical predictions to be extremely precise. We present transverse momentum resummed calculations at next-to-next-to-next-to-leading-log plus next-to-next-to-leading-order (*i.e.,* N^{3}LL+NNLO) accuracy for theZZ,WW, WZ,WHandZH processes and compare our predictions with most recent LHC data. We also offer predictions with uncertainty estimations for the LHC at 13.6 TeV energy. These calculations are made publicly available so as to allow future experimental analyses to take advantage of such improved predictions.
- The six orders of magnitude mass difference between the observed elementary fermions is one of the unresolved issues of fundamental physics. One line of thought is that such mass hierarchies results from quantum corrections. An explicit realisation of this idea based on new abelian gauge forces has been worked out and shown to be consistent with the experimental observations. Most importantly, it has been shown that the new forces must be flavour non-universal.

Collaborations of PRL with National/International institutions/universities

Astronomy and Astrophysics

- **Area of Collaborations:** Daksha mission, Future Broad-band X-ray Astronomy mission, Scientific analysis and interpretation of Chandrayaan-2/XSM observations, AstroSat-CZTI data analysis, Soft X-ray Spectral Diagnostics of Multi-thermal Plasma in Solar Flares, Role of Small-scale Impulsive Events in Heating the X-Ray Bright Points of the Quiet Sun, Multiwavelength Observations by XSM, Hinode, and SDO of an Active Region. Chemical Abundances and Temperatures, Role of spicules to heat the solar corona, Optical observations and dust modelling of comet 156P/Russell-LINEAR, Peculiar motion of Solar system from the Hubble diagram of supernovae Ia and its implications for cosmology, TOI 4603b, a Massive Giant Planet and most dense Exoplanet Discovered with PARAS Spectrograph, IC 5146 Dark Streamer: The First Reliable Candidate of Edge Collapse, Hub-filament Systems, and Intertwined Sub-filaments, "Probing the role of ionized, dust, and molecular filaments in massive star-forming sites around l = 345.5 degree, " New evidences in IRDC G333.73+0.37: colliding filamentary clouds, hub-filament system, and embedded cores, Simultaneous evidence of edge collapse and hub-filament configurations: A rare case study of a Giant Molecular Filament G45.3+0.1, Unraveling the observational signatures of cloud-cloud collision and hub-filament systems in W31, Tracers of Dense Gas in the Outer Galaxy, Probing the global dust properties and cluster formation potential of the giant molecular cloud G148.24+00.41, Investigating stellar variability in the open cluster region NGC 381, Optical Linear Polarisation Study toward Czernik 3 Open Cluster at Different Spatial Scales, Swift and XMMNewton observations of an RS CVn-type eclipsing binary SZ Psc: superflare and coronal properties, Optical and X-ray studies of Be/X-ray binary 1A 0535+262//HD 245770 during its 2020 giant outburst, Detection of a massive Galactic black hole in MAXI J1631–479 using X-ray spectroscopy, AstroSat Observation of X-ray Dips and State Transition in the Black Hole Candidate MAXI J1803-298, Evidence of heavy obscuration in the low-luminosity AGN NGC 4941, Absorption Variability of the Highly Obscured Active Galactic Nucleus NGC 4507, Broadband X-ray Spectroscopy and Estimation of Spin of the Galactic Black Hole Candidate GRS 1758-258, Search and Characterization of Remnant Radio Galaxies in the XMM-LSS Deep Field, Characteristics of remnant radio galaxies detected in deep radio continuum observations from SKA pathfinders, Detection of radio-AGN in dust-obscured galaxies using deep uGMRT radio continuum observations, Evidence of jet-induced optical microvariability in radio-loud narrow-line Seyfert 1 galaxies, PRL 2.5-m Project, PARAS-2 instrument for the 2.5 m telescope, Faint Object Camera, Near infrared background with the 1.2 m telescope at Mount Abu, NISP instrument development for the 2.5 m telescope, Adaptive Optics (AO) System Development, Development of Mt. Abu Faint Object Spectrograph and Camera - Echelle Polarimeter (M-FOSC-EP) for PRL 2.5m Telescope, Development of ProtoPol : A Prototype Spectro-polarimeter, Experimental verification of off-axis polarimetry with cadmium zinc telluride detectors of AstroSat-CZT Imager, Extending the energy range of AstroSat-CZTI up to 380 keV with compton spectroscopy, Development of Low Resolution Spectrograph
- **Collaborating Institutes/Universities:** IIT Bombay, Mumbai; TIFR, Mumbai, SAG-URSC, Bangalore; RRI, Bangalore, Atomic Astrophysics group at DAMTP, CambridgeUniversity, UK; STIX group Solar Orbiter mission, ESA; Heliophysics group, GSFC, NASA; Solar physics group, NASA Goddard Space Flight Center, USA,DAMTP, University of Cambridge, UK, NASA Marshall Space Flight Center, USA., Harvard-Smithsonian Center for Astrophysics, USA., NASA, GSFC, IIA, Bangalore,Instituto de Astrofsica de Canarias, Spain(Cometografia.es, Spain)., Thringer Landessternwarte Tautenburg, Germany., Universit Paris-Saclay, Universit Paris Cit, CEA, CNRS, AIM, 91191, Gif-sur-Yvette, France,Department of Astronomy and Space Science, Chungnam National University, Daejeon, Republic of Korea, Dublin Institute for Advanced Studies, 31 Fitzwilliam Place, Dublin D02XF86, Ireland), Korea Astronomy and Space Science Institute, 776 Daedeokdae-ro, Yuseong-gu, Daejeon 34055, Republic of Korea, Satyendra Nath Bose National Centre for Basic Sciences, Block-JD, Sector-III, Salt Lake, Kolkata-700 106, Institute of Applied Physics of the Russian Academy of Sciences, 46 Ulyanov st., Nizhny Novgorod 603950, Russia, Department of Astronomy and Astrophysics, Tata Institute of Fundamental Research., National Astronomical Observatory of Japan, Mitaka, Japan, Department of Physics, Nagoya University, Japan., IISER Tirupati, The University of Texas, USA; KASI, Kee-Tae Kim (KASI, UST, Republic of Korea) and other collaborators from various national and international institutes/organizations., JBCA, The University of Manchester, UK, LAM, France and other collaborators from various national and international institutes/organizations., ARIES, Nainital, Ravishankar Shukla University, Raipur, Key Laboratory for Research in Galaxies and Cosmology, University of Science and Technology of China, Chinese Academy of Sciences, Hefei, Anhui, Peoples Republic of China., ARIES, Nainital, Institute of Astronomy, Russia., National Space Institute, Denmark and Institute of Astronomy, National Tsing Hua University, Hsinchu, Taiwan., Cahill Center for Astronomy and Astrophysics, California Institute of Technology, USA., National Space Institute, Denmark and Universidad Metropolitana de Ciencias de la Educacion, Chile., Universidad Diego Portales, Santiago,

Chile, The University of Tokyo, Japan., Institute of Astronomy, National Tsing Hua University, Taiwan, University of Manitoba, Canada., NCRA-TIFR Pune, Oxford University., IES Nainital, Central University of Himachal Pradesh, Dharamshala, Astronomy and Astroparticle Physics, Alba Nova University Center, Stockholm, Sweden, South African Astronomical Observatory, Cape Town, South Africa, Centre for Space Research, North-West University, South Africa)., Stanford University, USA, TIFR, Mumbai, IUCAA Pune, Ashoka University., Stanford University, USA, TIFR, Mumbai, IIT Bombay, Ashoka University.

Solar Physics

- **Area of Collaborations:** A Parametric Study of Performance of Two Solar Wind Velocity Forecasting Models During 20062011, A study of the propagation of magnetoacoustic waves in small-scale magnetic fields using solar photospheric and chromospheric Dopplergrams: HMI/SDO and MAST observations, An effective generalized mechanism responsible for the production of broad CMEs resulting from compact solar eruptive flares, Calibration and performance evaluation of a monomorph deformable mirror, Comparison of the Hall Magnetohydrodynamics and Magnetohydrodynamics Evolution of a Flaring Solar Active Region, Effects of Initial Conditions on Magnetic Reconnection in a Solar Transient, Evolution of magnetic fields and energy release processes in an efficient magnetically coupled solar atmosphere, Global Oscillation Network Group (GONG) Program, Magnetic reconnections as the underlying cause of spontaneous generation and annihilation of three-dimensional magnetic nulls, Near-Earth Interplanetary Coronal Mass Ejections and Their Association with DH Type II Radio Bursts During Solar Cycles 23 and 24, Solar Hysteresis Pattern and Spectral Components in TEC Time Series (GPS and TIE-GCM) of the Quadrilaterally Coupled Geomagnetic Conjugate Low-latitude Stations, Sustained Heating of the Chromosphere and Transition Region Over a Sunspot Light Bridge.
- **Collaborating Institutes/Universities:** NASA/Marshall Space Flight Center, University of Alabama in Huntsville, USA, University of Oslo, Norway, Korea Astronomy and Space Science Institute, Republic of Korea, National Solar Observatory, USA, California State University, Northridg, School of Information and Physical Sciences, University of Newcastle, Callaghan, NSW 2308, Australia, Institute of Theoretical Astrophysics, University of Oslo, Postboks 1029, Blindern NO-0315 Oslo, Norway, Center for Space Plasma & Aeronomic Research, The University of Alabama in Huntsville, Huntsville, AL 35899, USA, Korea Astronomy and Space Science Institute, Daejeon 34055, Republic of Korea, Kyung Hee University, Yongin, Republic of Korea, National Solar Observatory, Boulder, CO, USA, Indian Institute of Astrophysics, Bengaluru., Max-Planck-Institut für, Göttingen, Germany.

Space and Atmospheric Sciences

- **Area of Collaborations:** Air pollution from informal electronic waste recycling and allied sectors in India, Air quality assessment techniques, Atmospheric Boundary Layer Over Ahmedabad, Western Indian Region: Impact of COVID-19 Nationwide Lockdown, Balloon borne observations of tropopause aerosol layer, CarbOnaceous AerosoL Emissions, Source apportionment & ClimatE impacts (NCAP-COALESCE), Characterization of Biogenic Volatile Organic Compounds (BVOCs) from common tropical plant species, Chemical composition and radiative forcing of atmospheric aerosols over the high altitude western Himalays of India, Daytime equatorial dynamics, Daytime upper atmospheric dynamics, Development of automation software for Short Wave Infrared Imager (SIRI), Differential behaviors of suprathermal ^{4}He and Fe populations in the interplanetary medium during solar cycle 24, Effect of lockdown on pollutant levels in the Delhi Megacity: Role of local emission sources and chemical lifetime, Effect of the sea and land breeze circulations in the levels and compositions of VOCs in the coastal environments, Equatorial F-layer vertical drift, Equatorial dynamics in the nighttime, Equatorial electrojet and counter electrojet, Evidence for presence of a global quasi-resonant mode of oscillations during high-intensity long-duration continuous AE activity (HILDCAA) events, GAGAN SBAS TEC, Geomagnetic storm, Investigate relationship between PM (particulate matter) and ozone over different urban environment in India, Investigation of Atmospheric Clouds Boundary Layer over Central India region, Investigation of Atmospheric Clouds Boundary Layer over Indo-gangatic region, Investigation of Atmospheric Clouds Boundary Layer over Leh-Ladhak region, Investigation of Atmospheric Clouds Boundary Layer over eastern part of the North-Eastern Indian region, Investigation of behaviour of cloud base height over North-East Indian region, Ionospheric Physics, Ionospheric daytime conjugate hemispheric asymmetry along 100°E longitude: New insights, Ionospheric response to space weather events, Low latitude ionospheric electrodynamics, MLT region wave dynamics, MSTID physics, Mesospheric wave activities, Metals in coarse ambient aerosol as markers for source apportionment, Middle atmospheric wave dynamics, Optical experiments for upper space weather studies, Photochemical ageing of primary VOCs, Prompt penetration electric field, Radiation belt physics, Relative roles of IMF B_z and B_y in generating global asymmetry in ΔX variations during a geomagnetic storm, Ring current asymmetry, Role of IMF B_y and substorm in generating anomalous electric field perturbations in the equatorial ionosphere during post-sunset hours, Role of common indoor plants in modulating indoor air quality, SSW influence on the MLT dynamics, temperature, and meridional circulation, SWASTi-SW: Space weather adaptive simulation framework for solar wind and Its relevance to the Aditya-L1 mission, Solar flux dependence of postsunset enhancement in vertical total electron content over the crest region of equatorial ionization anomaly, Solar wind and Heliospheric physics, Statistical investigation on equatorial pitch angle distribution of energetic electrons in Earth's outer radiation belt during CME- and CIR-driven storms, Substorm and Radiation belt physics, The behavior of cloud base height over a hilly remote station of North-East India using ground-based remote sensing technique.
- **Collaborating Institutes/Universities:** Andhra University, Visakhapatnam, British Antarctic Survey, Cambridge, UK, CSIR-NIO, Goa, Central University of Rajasthan, Ajmer, Department of Astronomy, Astrophysics and Space Engineering, IIT Indore., Department of Atmospheric

Science, Central University of Rajasthan, Ajmer 305801, and others., Department of Mathematics, Physics and Electrical Engineering, Northumbria University, UK, Space Science and Applications Group, Los Alamos National Laboratory, US, Laboratory of Atmospheric and Space Physics, University of Colorado Boulder, US., Department of Physics, University of Dibrugarh, Dibrugarh, Space Weather Services, Bureau of Meteorology, Surry Hills, New South Wales, Australia, National Institute of Information and Communications Technology, Japan, King Mongkuts Institute of Technology Ladkrabang, Bangkok, Thailand, Chiang Mai University, Chiang Mai,Thailand, Indonesian National Institute of Aeronautics and Space, Indonesia, Institute of Geophysics, Vietnamese Academy of Science and Technology, Hanoi, Vietnam]., Dibrugarh University, IIT Madras, ECMWF UK, NASA GSFC., Environment and Sustainability Department, CSIR- Institute of Minerals and Materials Technology, Bhubaneswar, Environmental Pollution Assessment Laboratory, Doon University, Dehradun, 248001, India, GFZ German Research Centre for Geosciences, Postdem, Germany, Dept. of Astronomy and Space Science, College of Natural Sciences, Chungnam National University, Daejeon, South Korea, ISAS, Department of Physics and Engineering Physics, University of Saskatchewan, Saskatoon, Saskatchewan, Canada], Vikram Sarabhai Space Centre, Space Physics Laboratory, Thiruvananthapuram, Leibniz-Institute of Atmospheric Physics, Kuhlungsborn, Germany, Discipline of Physics, University of Kwazulu-Natal, Durban, South Africa., GSFC-NASA, IAP, Germany, IIG-Navi Mumbai, IIT Delhi, IIT-Indore, IIT-Roorkee, ISEE, Nagoya University, Japan, Indian Institute of Astrophysics (IIA), Bangalore, Indian Institute of Geomagnetism, Navi Mumbai, Indian Institute of Technology (IIT), Indore, Indian Institute of Technology Kanpur, Paul Scherrer Institute, Switzerland, Indian Institute of Technology Delhi., Indian Institute of Technology, Bombay, Mumbai, Indian Institute of Technology, Roorkee, India, Institute for Advanced Sustainability Studies, Potsdam, Germany., Instituto Nacional de Pesquisas Espaciais, Brazil, Jawaharlal Nehru Technological University Hyderabad, Laboratory for Atmospheric and Space Physics, USA, Leibniz Institute for Atmospheric Physics (IAP), Germany, Los Alamos National Laboratory, USA, Lucknow center of ISTRAC (ISRO) Bangalore, Medium Frequency Radar Facility, Indian Institute of Geomagnetism, Shivaji University Campus, Kolhapur, Multi Institute National Project with IIT Bombay as lead institute, Multi institute field campaign with NASA Langley Research Center, Hampton, VA, USA as lead institute., NCMRWF, MoES, Delhi, SAC, ISRO., NE-SAC, Shillong, NESAC, Umiam, Meghalaya, Cotton University, Assam, IMD, New Delhi., NPL and IIT Delhi, Nagoya University, Japan, National Institute for Space Research, São José dos Campos, São Paulo, Brazil, Campina Grande, Paraiba, Brazil, British Antarctic Survey, Cambridge, UK., Northumbria University, UK, SRM Institute of Science and Technology, Chennai, Space Physics Laboratory, Trivandrum., Space Physics Laboratory, Vikram Sarabhai Space Centre, Trivandrum, Universidade do Vale do Paraiba (UNIVAP), Brazil., University of Mumbai, University of Saskatchewan, Canada, Unviersidade do Vale do Paraiba, Brazil, Utah State University, Logan, UT, USA, Space Science and Applications Group, Los Alamos National Laboratory, US, GFZ German Research Centre for Geosciences, Potsdam, Germany, Indian Institute of Geomagnetism, Navi Mumbai, Airport Authority of India, Ahmedabad.

Planetary Sciences

- **Area of Collaborations:** Abiotic synthesis of methane at the recess of Martian crust and prospect of microbial life in the Noachian Mars- CLASS-M3 based elemental estimation of Moon surface, ChaSTE Payload Development for Chandrayaan-3 Lander, Constraints from experimental and meteorite studies, Dust Dynamics, Experimental Simulation of Lightning and Development of Lightning Detection Antenna for Future Planetary Missions, Explore the terrestrial impact craters, Geochemical study based on Planetary mission data for Martian surface, Lunar Floor Fractured craters: A reappraisal of their Genesis, Plasma Physics (Project: Acoustic Solitary/ Shock Waves in Multicomponent Quantum Magneto Plasma: Application in Communication Technology), Plasma environment on Moon (Project: Effect of protons in the near lunar wake on the nightside surface charging), Reiner Gamma swirl study using polarimetric imaging, Satellite Charging, Understanding the impact melt distribution on fresh lunar craters, Satellite Charging, Plasma environment on Moon (Project: Effect of protons in the near lunar wake on the nightside surface charging, Machine learning based detection of Mg-Spinel, CLASS-M3 based elemental estimation of Moon surface, Reiner Gamma swirl study using polarimetric imaging, Abiotic synthesis of methane at the recess of Martian crust and prospect of microbial life in the Noachian Mars- Constraints from experimental and meteorite studies, Explore the terrestrial impact craters.

- **Collaborating Institutes/Universities:** CHARUSAT, Changa, Cambridge, UK, New Mexico State University, USA., Center for Space Physics, Boston University, Boston, MA, USA, Space Physics Laboratory, VSSC, Trivandrum, Instituto de Astrofísica de Andalucía-CSIC, Granada, Spain., Scripps Institution of Oceanography, University of California, USA. National Institute of Polar Research, Japan, The Kyoto University Museum, Kyoto University, Japan, Department of Computer Science, Gujarat University, Dept. of Applied Sciences, Guwahati University, Guwahati-781014, Dortmund University of Technology, Germany., IPR, Bhat., Government College of Salem, Khalifa University, UAE, Laboratoire de Planétologie et Géodynamique, Nantes, CNRS, Auburn University, USA, IISC Bangalore, IIT Gandhinagar, IPR, Bhat., Indian Institute of Technology (ISM), Dhanbad, Baylor University, USA., Université de Toulouse, France, Louisiana State University, USA., IIT, Kharagpur, ICATE-CONICET, San Juan, Argentina., CSIR-National Institute of Oceanography, Goa,. NISER, Jatni Odisha, JPL, Caltech, Pasadena, USA. University of Oxford, UK, Cavendish Laboratory and University of National Center for Earth Science Studies, Thiruvananthapuram, Space Physics Laboratory, VSSC, Trivandrum., National Geophysical Research Institute, Hyderabad, National Institute of Polar Research, Japan, Presidency University, Kolkata, JJT University, Rajasthan, Space Physics Laboratory, Vikram Sarabhai Space Centre, Thiruvananthapuram 695024, Technical University Dortmund, Dortmund, Germany, Anna University, U R Rao Satellite Centre, ISRO, University of Western Ontario, Canada.

Geosciences

- **Area of Collaborations:** Atmospheric deposition and Ocean biogeochemistry., Basin-scale N_2 fixation, Composition of UTLS aerosols, Effect of aerosols on solar cell, Experimental study of chemical weathering of basalt, Geochemical study of Tertiary Sediments from Tripura Area., Geochemical weathering of Rajmahal basalt., Lake Biogeochemistry, Landform evolution and natural hazards in the Garhwal Himalaya, Marine biogeochemistry, Nitrogenous aerosols over Himalaya, Ore Geology, Paleoclimate and human settlements, Past monsoon and modern climatology, Weathering pattern of basalt in different climatic regime, Model based examination of radiocarbon contribution from Indonesian throughflow to the south-eastern tropical Indian Ocean, Spatial heterogeneity in beryllium isotopic distribution in the Indian Ocean, Seasonal variation of surface seawater radiocarbon in the Andaman Sea as recorded in corals, Relict proglacial lake of Spituk (Leh), northwest (NW) Himalaya: A repository of hydrological changes during Marine Isotopic Stage (MIS)-2, Southern hemisphere forced millennial scale Indian summer monsoon variability during the late Pleistocene, New insights into diffusive kinetic fractionation during liquid condensation under supersaturated environment: an alternative approach for isotope tagging of ground-level water vapour, Surface water-groundwater interaction in water-stressed semi-arid western India: Insights from environmental isotopes, Investigating hydrometeorology of the Western Himalayas; Insights from stable isotopes of water and meteorological parameters, Extreme local recycling of moisture via wetlands and forests in NorthEast Indian subcontinent: a Mini-Amazon, Control of regional climate on carbon and nitrogen turnover in Indian soils, Fire and precipitation history of the Kashmir Himalaya during the last four thousand years, Effect of tidal cycle on greenhouse gases, Nitrous oxide in the central Bay of Bengal, Oxidative Potential and Hydroxyl Radical Generation Capacity of Ambient $PM_{2.5}$ over a High-Altitude Site in Northeastern Himalaya: Role of Long-Range Transport, Characterization of paddy-residue burning derived carbonaceous aerosols using dual carbon isotopes, Assessment of aeolian dust concentration, elemental composition and their wet and dry deposition fluxes over the north Arabian Sea, Contribution of Carbon Fixation Toward Carbon Sink in the Ocean Twilight Zone, Convective mixing and transport of the Bay of Bengal water stir the δ^{18}O-salinity relation in the Arabian Sea, Impact of suboxic/hypoxic water column conditions in the Arabian Sea on Mo isotopic composition (δ^{98}Mo) in Arabian Sea, Mountain highway stability threading on the fragile terrain of upper Ganga catchment (Uttarakhand Himalaya), India, Emergent interactive effects of climate change and contaminants in coastal and ocean ecosystems.
- **Collaborating Institutes/Universities:** CNRS, France, CSIR-NIO, Goa, Central University of Himachal Pradesh, Centre for Marine Living Resources and Ecology, Cochin, HNBGU, Srinagar Garhwal, Hyderabad University, IISER Kolkata, IIT Bombay, IIT Gandhinagar, IITM, Pune, Indian Institute of Science Education and Research, Mohali, Indian Institute of Space Science and Technology, Trivandrum., Indian Institute of Technology, Kharagpur, JNU, New Delhi, Kashmir university, Srinagar, Mediterranean Institute of Oceanography (MIO), Marseille, France, Pachhunga University College, Aizal, INCOIS, Hyderabad, NRSC, Hyderabad., NE-SAC, CSIR-NIO, Goa.

Atomic, Molecular and Optical Physics

- **Area of Collaboration:** A tolerance-enhanced spontaneous parametric down conversion source of bright entangled photons, ALMA Survey of Orion Planck Galactic Cold Clumps (ALMASOP): Density Structure of Centrally Concentrated Prestellar Cores from Multiscale Observations, An Early Presence of Modern Human or Convergent Evolution **?** A 247 ka Middle Palaeolithic Assemblage from Andhra Pradesh, India, Anisotropic spatial entanglement, Assessing slow-down times due to blackbody friction forces for high-precision experiments, Assessing the Precision of Quantum Simulation of Many-Body Eects in Atomic Systems using the Variational Quantum Eigensolver Algorithm, Augmenting data security: physical unclonable functions for linear canonical transform-based cryptography, BBM92 quantum key distribution over a free space dusty channel of 200 meters, Controlling the Coverage of Full Poincar Beams through Second-Harmonic Generation, Determination of C_5 dispersion coefficients of the alkali atoms interacting with different material media, Dynamical charge inversion of polarization correlation vortex in a propagating vector speckle field, East Antarctica ice sheet in Schirmacher Oasis, Central Dronning Maud Land, during the past 158 ka., Electric Dipole Moments and Static Dipole Polarizabilities of Alkali-Alkaline-Earth Molecules: Non-relativistic versus relativistic coupled-cluster theory analyses, Higher-order photon statistics as a new tool to reveal hidden excited states in a plasmonic cavity, Indistinguishable photons, Isotope Shifts in Cadmium as a Sensitive Probe for Physics Beyond the Standard Model, Luminescence Dating and Bracketing Time of the Youngest Toba Tuff Deposits in the Quaternary Sediments of Purna Alluvial Basin, Central India, Luminescence Dating of Quartz: A MATLAB-Based Program for Computation of SAR paleo-doses using natural sensitivity correction (NCF), Multispectral athermal fading rate measurements of K-feldspar., N-graphene synthesized in astrochemical ices, Observing polarizationorbital angular momentum entanglement duality, Polarization effects, shape resonances, and bound states in low energy positron elastic scattering by Zinc and Cadmium vapors, Precision measurement of the magnetic octupole moment in ^{45}Sc as a test for state-of-the-art atomic- and nuclear-structure theory, Relativistic normal coupled-cluster theory analysis of second-and third-order electric polarizabilities of Zn I., Role of plasma temperature and electron number density on signal enhancement observed in nanoparticle-enhanced LIBS-, Shock-induced transformation of non-magnetic to magnetic ISM dust analogue, Speckle-based deep learning approach for classification of orbital angular momentum modes, Strong-field ionization of N_2 and CO molecules using two-color laser field:, Strong-field ionization of CH_3Cl: proton migration and association:, The dominant role of deglaciation in Late PleistoceneEarly Holocene sediment aggradation in the Upper Chenab valley, NW Himalaya.
- **Collaborating Institutes/Universities:** Centre for Quantum Engineering, Research and Education, TCG CREST, Salt Lake, Kolkata, India; and Department of Physics, Tokyo

Institute of Technology, Ookayama,Meguro-ku, Tokyo, Japan, Department of Physics, Guru Nanak Dev University, Amritsar, Punjab, Department of Physics, NIT Warangal, Department of Physics, University of Jyvskyl, Department of Physics, University of Liverpool, Liverpool, United Kingdom; Sino-French Institute of Nuclear Engineering and Technology, Sun Yat-Sen University, Zhuhai, China, Department of Physics, University of York, Heslington, York, United Kingdom; Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg, Berlin, Germany; Department of Physics, Pennsylvania State University, University Park, State College, PA, USA., GSI Nagpur; GSI, Patna, GSI Faridabad, IITGN; IITRAM Ahmedabad, the ALMASOP international team., Institute for Particle Physics and Astrophysics, ETH Zurich, CH Zrich, Switzerland; Institute for Theoretical Physics, FAU Erlangen-Nurnberg, 91058 Erlangen, Germany; MSU Baroda., Physics Department, Universidade Federal de Santa Catarina, Florianopolis, Santa Catarina, Brazil and Physics Department, Universidade Federal de Pelotas, Pelotas, Rio Grande do Sul, Brazil, SRM UniversityAP, Amaravati, University of Malaya Malaysia, SGB Amravati University, University of the Witwatersrand, South Africa.

Theoretical Physics

- **Area of Collaborations:** Analytic treatment of 3-flavor neutrino oscillation and decay in matter, Anatomy of scalar mediated proton decays in SO(10) models, Axion dark matter, Forbidden freeze-in dark matter, Condensed Matter Physics, DUNE, Energizing gamma ray bursts via $Z^{'}$ mediated neutrino heating, Forbidden freeze-in dark matter, Freeze-in dark matter through a tangibly forbidden channel, High Energy Physics, INO, IRC-safe Graph Autoencoder, Leptogenesis with eV scale sterile neutrino, Light Cone Sum Rules and Form Factors $p \to e^{+}\gamma$, Lowering the scale of fermion triplet leptogenesis with two Higgs doublets, Neutrino Physics, Neutrino Propagation When Mass Eigenstates and Decay Eigenstates Mismatch, Non-local slicing approaches for NNLO QCD in MCFM, Precise probing of the inert Higgs-doublet model at the LHC, Radiatively generated fermion mass hierarchy from flavor nonuniversal gauge symmetries, Self- interacting freeze-in dark matter, Spectrum of color sextet scalars in realistic SO(10) GUT, Statistical Nuclear Spectroscopy with q-normal and bivariate q-normal distributions and q-Hermite polynomials, The case of itinerant magnetism in $CaMn_2Al_{10}$: self-consistent renormalisation (SCR) theory study, Top-philic dark matter in a hybrid axion framework, Transport signatures of a topological superconductor junction, Tunable phase transitions in half-Heusler TbPtBi compound.
- **Collaborating Institutes/Universities:** Autonomous University of Madrid, Spain, Uppsala University, Sweden., Brookhaven National Laboratory, USA, Fermilab, USA, Harish-Chandra Research Institute (HRI), Allahabad, IIT Kanpur, IMSC, Chennai, IPPP, Durham University, UK, Fermilab, USA., Indian Association for the Cultivation of Science (IACS), Kolkata, Indian institute of Mathematical Sciences, Chennai, University of Kolkata , Kolkata, Instituto de Ciencias Fêsicas, UNAM, Cuernavaca, Mexico., Kyungpook National University, Republic of Korea., IIT Kanpur National Center of Nuclear research, Warsaw, TIFR, Mumbai, Tata Institute of Fundamental Research, Mumbai, National Centre for Nuclear Research Warsaw, Poland., Indian Institute of Science Education and Research, Pune., University of Glasgow, UK, University of Valencia Spain, Uppsala University, Sweden.

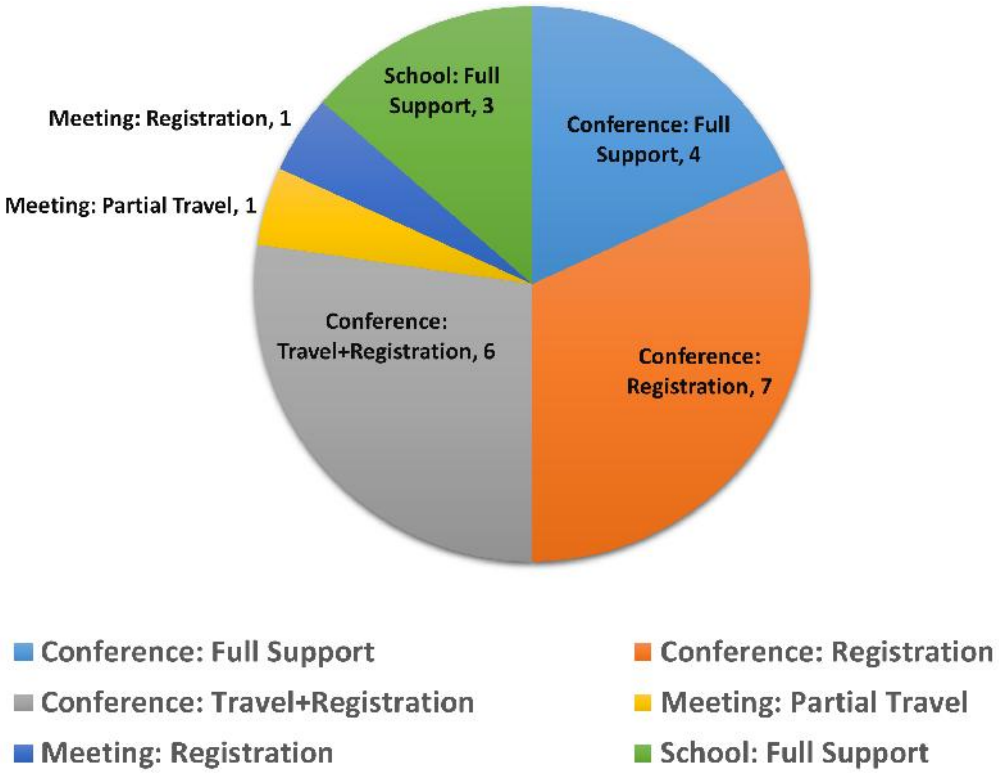
Externally Funded Project in PRL

Sr. No.	Funding agency	PI	Status	Duration	Broad Area
1.	DST	R P Singh	Active	2019-2022	Quantum I.T Photonic Devices
2.	DST/SERB	Brajesh Kumar	Active	2020-2022	Solar Dynamics and Space Weather
3.	Indo Uzbek SWC	Nandita Srivastava	Active	2021-2024	Space Weather
4.	Indo-U.S. Science and Technology Forum	Nandita Srivastava	Active	2021-2024	Space Weather
5.	DST CEFIPRA	Kuljeet Kaur Marhas	Active	2021-2024	Study of Chondrites
6.	Europlanet 2024	Kuljeet Kaur Marhas	Active	2021-2022	Study of Chondrites
7.	DST CEFIPRA	Neeraj Rastogi	Active	2021-2023	Exploring the Asian pollution signature
8.	ISRO-NASA (Co-PI)	Neeraj Rastogi	Active	2021-2024	Investigation of the Stratospheric Aerosols
9.	DST	Arvind Singh	Active	2022-2026	Biogeochemical Cycling
10.	DST CEFIPRA	Arvind Singh	Active	2020-2023	Dinitrogen Fixation in the Indian Ocean
11.	MoES	Arvind Singh	Active	2022-2025	Biogeochemical Processes in Marine Carbon
12.	CARS	Goutam K Samanta	Active	2021-2023	Photonics
13.	SERB (MATRICS)	Ketan Patel	Active	2022-2025	Baryogenesis in Grand Unified Theories
14.	DST (INSPIRE)	Ketan Patel	Active	2015-2021	Standard Model Flavour Puzzle in Higher Dimension
15.	Europlanet grant	B. Sivaraman	Active	2021-2022	Astrochemistry
16.	The Royal Soc. Int. Exchange Grant with Uni. of Kent, UK	B. Sivaraman	Active	2020-2022	Astro chemical ices
17.	Europlanet grant to visit DLR, Berlin (Germany)	B. Sivaraman	Active	2022	Spectroscopy of shock processed planetary analogues

Sr. No.	Funding agency	PI	Status	Duration	Broad Area
18.	Beamtime grants, NSRRC, Taiwan	B. Sivaraman	Active	2021-2023	VUV Spectroscopy of Astrochemical ices
19.	DAAD-Research Internships in Science and Engineering Worldwide (Germany)	B. Sivaraman	Active	2022	Research Internships in Science and Engineering
20.	Europlanet Transnational access grants [Fast track]	Surendra Vikram Singh	Active	2022	Identifying the biosignatures on icy moons
21.	DST	Varun Sheel	Active	2023-2025	Study of the Venusian climate
22.	SERB-CRG	Varun Sheel	Active	2023-2026	Study of Climate of Mars
23.	Indo-German DST-DAAD personnel exchange program	Bhuwan Joshi	Active	2023-2025	Exploration of solar flare X-ray emission
24.	SERB-DST	Srubabati Goswami	Active	2020-2025	Probing BSM physics through neutrinos
25.	SERB-DST	Ketan Patel	Active	2022-2025	Quantifying Baryogenesis in Grand Unified Theories
26.	SERB-DST	Paramita Dutta	Active	2023-2025	Signatures of emergent phases of matter in transport phenomena
27.	SERB-DST	Satyajit Seth	Active	2023-2026	Precision calculation via non-local slicing
28.	ISRO-GBP	Arvind Singh	Active	2020-2024	Marine Carbon: Nitrogen: Phosphorous(C:N:P) stoichiometry
29.	MoES	Arvind Singh	Active	2022-2025	Role of Biogeochemical processes in controlling marine Carbon
30.	ISRO-GBP	Arvind Singh	Active	2019-2024	Nitrogen and carbon cycling in soils of different ecozones of India
31.	MoES	Sanjeev Kumar	Active	2021-2026	Unravelling the food-web dynamics and energy flow in the northern Indian Ocean

Sr. No.	Funding agency	PI	Status	Duration	Broad Area
32.	SERB	Shubhra Sharma	Active	2020-2023	Late Quaternary glacier advances in NW Himalaya
33.	DST	Shubhra Sharma	Active	2017-2023	Paleo-floods in the western Himalaya
34.	SERB-DST	Amzad hussain Laskar	Active	2021-2022	Tropical soil carbon dynamics
35.	SERB-DST	Vineet Goswami	Active	2021-2023	Reconstruction of Neoproterozoic ocean redox

Summary of PRL Members supported to attend International Conferences/Meetings/Schools



Field work/ Campaigns/ Observations Conducted

Space and Atmospheric Sciences

1. **Objective:** Measurement and identification of the major Biogenic Volatile Organic Compounds (BVOCs) emitted from tropical plant species of India using a branch enclosure experiment.
   Duration: October 2022
   Type of fieldwork: Branch enclosure experiment in forested area.
   Outcome: Characterization of BVOCs from common tropical plant species of India, and their impact on VOC composition of coastal regions of south-western India.
   Implications Significance: Estimate of air-sea exchanges of reactive trace gases and variation over the northern Indian Ocean is important to understand role in atmospheric chemistry
   PRL Members Participated in Fieldwork: Prof. Lokesh Sahu, Dr Tanzil Malik, Ms Mansi Gupta

2. **Objective:** Experimental campaign at IIT Delhi to study the role of common indoor plant species in modulating the indoor air quality.
   Duration: March 2023
   Type of fieldwork: Plant chamber experiment in laboratory
   Outcome: Characterization of types of VOCs emitted from potted plant species and the role of environmental factors in controlling the emissions.
   Implications Significance: Will be important in understanding the emissions of reactive trace gases from plants in indoor conditions like offices and homes, and implication of these plants on human health, in context of VOCs.
   PRL Members Participated in Fieldwork: Prof. Lokesh Sahu, Ms Mansi Gupta

3. **Objective:** Effect of the sea and land breeze circulations in the levels and compositions of VOCs in the coastal environments.
   Duration: Nov 2022- April 2023(Ongoing)
   Type of fieldwork: Station-based ambient air observations
   Outcome: Emission and atmospheric processes of VOCs emitted from terrestrial and oceanic sources
   Implications Significance: Will be important to understand the biosphere-ocean-atmosphere processes controlling emission of VOCs and atmospheric chemistry in coastal region.
   PRL Members Participated in Fieldwork: Prof. Lokesh Sahu, Ms Mansi Gupta, Dr Tanzil Malik

4. **Objective:** To install the PRL Airglow Photometer for studying wave activities over the Himalayan region.
   Duration: 29 May 2022 to 04 June 2022
   Type of fieldwork: visited the Devasthal observatory maintained by Aryabhatta Research Institute of Observational Sciences, Nainital
   Outcome: .
   Implications Significance: .
   PRL Members Participated in Fieldwork: Dr. Amitava Guharay and Dr. Subarna Mondal

Planetary Sciences

5. **Objective:** To collect geological data and samples of hot spring deposits and other related rocks from the hot spring localities of Kasol and Manikaran
   Duration: From 15 Nov 2023 to 23 Nov 2023
   Type of fieldwork: Geological Sample collection
   Outcome: Maiden identification of Martian minerals from these hot spring deposits and establishment of these regions as Martian analog
   Implications Significance: Mineralogical characterization of the Hot Springs provide a good proxy for the search for bio-signatures and past water/rock activity on Mars
   PRL Members Participated in Fieldwork: Dwijesh Ray and Subham Sarkar

6. **Objective:** To collect geological samples for understanding the aqueous alteration in basaltic environment relevance to Mars
   Duration: From December 2, 2022 to December 4, 2022
   Type of fieldwork: Geological Sample collection
   Outcome: Sample process is ongoing, initial results suggested for iron enrichment in secondary minerals
   Implications Significance: The Fe-enrichment may be comparable to the oxidative alteration similar to the ancient Mars
   PRL Members Participated in Fieldwork: Dwijesh Ray, Anil D. Shukla, Subham Sarkar and Aditya Das

Geosciences

7. **Objective:** To study nitrogenous aerosols over Himalaya.
   Duration: From Dec 2022 to March 2023
   Type of fieldwork: Aerosol Sampling
   Outcome: Characterization of aerosols
   Implications Significance: For Ph.D work of Chandrima Shaw
   PRL Members Participated in Fieldwork: Neeraj Rastogi via collaboration.

8. **Objective:** A. To test the potential of enhanced ocean alkalinity for atmospheric CO_2 removal. B. To identify minerals that can be used to enhance ocean alkalinity in a sustained way. C. To examine the impact of increased ocean alkalinity on carbon, nitrogen and phosphorous cycles.
   Duration: From Nov - Dec, 2023
   Type of fieldwork: Mesocosm experiment

Outcome: This experiment will help to answer some fundamental questions on the scale of continental weathering and erosion in the geological past. Results obtained in this project might be used to interpret the geological records of continental weathering and erosion.
Implications Significance: We will have a concrete idea about up to what scale ocean alkalinity can be increased without disturbing the ecosystem and otherwise. The consequences (feedbacks) of alkalinity enhancement will be known. Since we aim to understand the consequences of enhanced ocean alkalinity, this research will tell if it is sustainable and advisable to enhance ocean alkalinity. In addition, it might help to decide the oceanic regimes where such experiments might be realizable.
PRL Members Participated in Fieldwork: Tatsat Solanki, Himanshu Saxena, Nazirahmed Sipai, Shreya Mehta, Jitender Kumar and Arvind Singh

9. **Objective:** The objective of this field trip was to conduct a study to understand cycling of nitrogen and carbon in Antarctica lakes with particular emphasis to greenhouse gases.
Duration: 2.5 months (November 2022 – January 2023)
Type of fieldwork: Sample collection
Outcome: After analyzing the samples collected from the work, it is expected that it would enhance our understanding of elemental cycling in low temperature pristine ecosystems.
Implications Significance: The results obtained may help to contribute to better constrain the greenhouse gas fluxes and budgets.
PRL Members Participated in Fieldwork: Siddhartha Sarkar

10. **Objective:** The objective the field works conducted is aimed to understand the effect of lake desiccation on cycling of nitrogen and carbon.
Duration: Nal Sarovar (during May and September 2022 and January 2023) and Thol (May and September 2022)
Type of fieldwork: Sample collection
Outcome: The outcome of this study would allow to understand the elemental cycling due to desiccation and increase in salinity of freshwater systems.
Implications Significance: The study would help to constrain the role of freshwater systems in emission of greenhouse gases.
PRL Members Participated in Fieldwork: Ajayeta Rathi, Atif Khan, Siddhartha Sarkar, Abdur Rahman and Sangeeta Verma

11. **Objective:** To estimate the residence times of groundwater, identify recharge zones, flow direction and velocity in the semi-arid regions of Gujarat.
Duration: 8 days between 22 March and 4 April, 2022
Type of fieldwork: Groundwater sample collection
Outcome: The analysis will help to understand the groundwater residence times in multilayered aquifers of semiarid and water stressed regions of Gujarat.
Implications Significance: The data will be helpful for formulating sustainable groundwater management policies.
PRL Members Participated in Fieldwork: Amzad Hussain Laskar, Abdur Rahman, Bankimchandra Pandya, Rahul Kumar Agrawal and Shreya Mehta

12. **Objective:** To understand the groundwater-river water interactions and causes of recent reduction in the Ganga summer base flow
Duration: 10 days between 22 June and 10 July, 2022
Type of fieldwork: Groundwater and river water sample collection
Outcome: The analysis will help to understand the contribution of groundwater in Ganga river base flow throughout its course during the dry summer season.
Implications Significance: The data will be helpful for taking necessary steps for sustainable flow in the Ganga River.
PRL Members Participated in Fieldwork: Amzad Hussain Laskar

13. **Objective:** To understand the tropical soil carbon dynamics
Duration: 9 days between 28 December, 2022 and 12 March, 2023
Type of fieldwork: Soil, soil CO_2 and soil N_2O sample collection from forest and agricultural lands of Gujarat
Outcome: The study will help to estimate the residence times of soil CO_2 and organic carbon in soils and the exact sources of the greenhouse gases CO_2 and N_2O emitted from soils.
Implications Significance: The data will be helpful for constraining the contribution of tropical soil CO_2 in the atmosphere for modelling future climate.
PRL Members Participated in Fieldwork: Bankimchandra Pandya, Rahul Kumar Agrawal and Ranjan Kumar Mohanty

14. **Objective:** For collection of geological samples from the different types of rocks (lithologies)of the Neotethyan ophiolite sequence exposed along the two major river valleys of the area: Lohit and Dibang
Duration: 10 Days
Type of fieldwork: Geological fieldwork; traversing and sample collection
Outcome: Understanding the behavior of slab-derived fluids and melts and their effects on the evolution of arc magmas and earths mantle compositions
Implications Significance: Fluids (H_2O and CO_2) play an important role in the evolution of earth and plate tectonic cycle. Furthermore, deep earth is believed to contain fluid reservoirs and subduction zones are considered to be involved in element recycling. Thus, studying the fluid composition of mantle rocks exposed on earth will help to characterize them and provide some insight on the role of plate tectonics in geochemical recycling. Furthermore, such studies can also act as baseline for more advanced studies regarding the earths internal composition and can be possibly extrapolated to other terrestrial planets, if they have any evidence of plate tectonics.
PRL Members Participated in Fieldwork: Amrita Dutt, Shivansh Verma and Ambili Narayanan

15. **Objective:** To collect samples from the different types of the Archean banded iron formations, including banded hematite quartzite, banded hematite jasper, and iron nodules from government and private iron mines in Tomka, Kiriburu, Meghatuburu, Noamundi, and Badamphar. The older metamorphic tonalite gneisses, which are the basement rocks of the Singhbhum craton and exposed near Champua and Rimuli were also sampled.
Duration: 10 Days
Type of fieldwork: understanding the evolution of the Fe reservoir of earth and explore the evolution of early Earth using non-traditional isotopes
Outcome: Understanding the evolution of the Fe reservoir of earth and explore the evolution of early Earth using

non-traditional isotopes
Implications Significance: Iron and other non-conventional stable isotopes hold the key to understand the accretion of early and its internal differentiation and evolution with respect to time. The availability of oxygen on earth is still a mystery and banded irons can play an important part in solving it.
PRL Members Participated in Fieldwork: Anil D. Shukla, Amrita Dutt, Shivansh Verma and Ambili Narayanan

16. **Objective:** Collection of sedimentary rock (shale) samples for geochemical and isotopic analyses.
Duration: From 20 March – 27 March 2023
Type of fieldwork: Sample Collection in Vindhyan basin.
Outcome: The collected samples are currently under analyses for trace elemental abundances and stable Mo isotopic composition (δ^{98}Mo) to understand the Neoproterozoic ocean redox. The collected data is expected to provide a comprehensive information about the redox state of the Neoproterozoic oceans and their evolution.
Implications Significance: The comprehensive understanding of redox state and evolution of the Neoproterozoic oceans will be helpful to establish linkages between the oxygenation of the earth's oceans and atmosphere and biological evolution through the timeframe.
PRL Members Participated in Fieldwork: Deependra Singh and Vineet Goswami

17. **Objective:** River erosion studies based on ^{10}Be in Fluvial Sediments in the Uttarakhand Himalayan region in Upper Ganga Catchment
Duration: from May 25 – June 12, 2022
Type of fieldwork: Sample collection at Uttarkhand Himalayan region
Outcome: River erosion rates in Uttrakhand Himalaya
Implications Significance: River erosion studies based on ^{10}Be in Fluvial Sediments in the Uttarakhand Himalayan region in Upper Ganga Catchment
PRL Members Participated in Fieldwork: Ravi Bhushan, Partha Sarathi Jena and Ankur Dabhi

18. **Objective:** Biogeochemical assessment of the Chandra River Basin focusing on the transport of carbon and nitrogen along with the evasion of greenhouse gases.
Duration: From 9 – 19 June, 2022
Type of fieldwork: Sample collection of river water and sediments.
Outcome: Sample analysis is ongoing
Implications Significance: The study has the potential to improve our understanding of glacier fed riverine systems in the Indian Himalaya. Understanding the dynamics of greenhouse gases in pristine environments is highly warranted to get an idea of the contribution of natural systems in global carbon and nitrogen budgets.
PRL Members Participated in Fieldwork: Siddhartha Sarkar

Awards and Honors

Faculty

Anil Bhardwaj

1. Distinguished Alumni Award of the University of Lucknow, Lucknow, 2022.
2. Awarded, Shree Pramukh Swami Maharaj Endowed Chair Professorship, P.D. Patel Institute of Applied Sciences, CHARUSAT, Changa, 2022.
3. Elected Council Member, National Academy of Sciences, India, Allahabad, 2023.
4. Nominated as Member, Governing Council, Indian Institute Astrophysics, Bangalore, 2023-2026.
5. Chief Guest, Inauguration of the National Conference on Advances in Physical Sciences for Sustainable Development (NCAPSSD2022), Department of Physics, Centre of Education, Indian Institute of Teacher Education (IITE), Gandhinagar, 27 August 2022.
6. Chief Guest, Inauguration for the Second National Virtual Conference on Space Science and Technology for School Students and Release of Antrix Udyog Magazine online, organised by Indian Space Industries Exhibitors (ISIE), 5 Sept. 2022.
7. Chief Guest, Inauguration of Atal Tinkering Lab (ATL), BAPS Swaminarayan Girls School, Randesan, Gandhinagar, 6 October 2022.
8. Chief Guest, Indian Institute of Technology Gandhinagar, Convocation GradWalk Ceremony, 23 Dec. 2022.

M. M. Sarin

9. Member, United Nations Group of Experts on Scientific Aspects of Marine Environmental Protection (UN/GESAMP). GESAMP is an interagency advisory body of the United Nations.
10. Co-chair, United Nations/GESAMP Working Group on "Climate Change and Greenhouse Gas Related Impacts on Contaminants in the Ocean" sponsored by IAEA (Monaco) as lead agency.
11. Member, Research Council of CSIR-National Institute of Oceanography, Goa.
12. Member, CSIR Expert/Monitoring Committee for NCP/FBR projects under the theme on Ecology, Environment, Earth, and Ocean Science & Water (E3OW)

S. A. Haider

13. Chair of Sub-Commission C3 in 44^{th} COSPAR Assembly held in Athens, Greece during 16-24, July 2022
14. Main Scientific Organizer (MSO) of C3.2 event held in 44^{th} COSPAR Scientific Assembly, Athens, Greece during 16-24 July, 2022.

Srubabati Goswami

15. Included as Council Member , Indian National Science Academy, 2023-2025
16. Elected as Vice President, Indian Physics Association 2023-2024
17. Received the Fulbright-Nehru Academic and Professional Excellence Fellowship 2023

Duggirala Pallamraju

18. Elected Fellow, Indian Academy of Sciences, 2023.
19. Speaker for the "5^{th} PRL-IAPT Dr. Vikram Sarabhai Lecture", entitled "Space research through Optical Window", delivered on 22 March 2023 at PRL, Ahmedabad.
20. Speaker for the "44^{th} IITM's Prof. R. Ananthakrishnan Colloquium", entitled, "Space Weather Science and its effect on Societal Applications", delivered on 13 February 2023 at IITM, Pune.

S. Ramachandran

21. Associate Editor, Frontiers in Environmental Science.
22. World's Top 2% Scientists, Stanford University.
23. Affiliate Scholar, Institute for Advanced Sustainability Studies, Potsdam, Germany.

Nandita Srivastava

24. Associate Editor of Journal of Space Weather and Space Climate (JSWSC) since November 2022
25. Member, Research Advisory Committee, Indian Institute of Geomagnetism, Mumbai since March 2023.

Ravi Bhushan

26. Member: Research Advisory Council, Birbal Sahni Institute of Paleosciences (2021-2024).
27. Associate Editor: Radiocarbon Journal
28. Associate Editor: Frontiers in Marine Sciences (Marine Biogeochemistry section)
29. Member, Editorial Board: Journal of Paleosciences
30. Member: INSA-SCOR (Since Jan 2020)
31. Adjunct Professor: Mangalore University, Mangalore

B. K. Sahoo

32. Listed among Top 2% of Scientists in the world in the respective research elds published in 2022 by Stanford University
33. Chaired a session in a conference organized at IUCAA on "Probing constancy of constants", 1-2 December, 2022
34. Elected as Vice-President of Indian Society Atomic and Molecular Physics (ISAMP) in February, 2023

D. Chakrabarty

35. Invited Reviewer, Regular Fondecyt National Projects Competition, National Research and Development Agency (ANID) of the Ministry of Science, Technology, Knowledge and Innovation of Chile, Gobierno de Chile.
36. Nominated Member, UNOOSA (United Nations Office for Outer Space Affairs) "Access to space for all" curriculum.
37. Invited Member, Research Advisory Committee, Institute of Astronomy, Space and Earth Science (IASES), Kolkata.
38. Invited Member, Scientific Organizing Committee (SOC), Science from In-situ Measurements from Aditya-L1 (SIMA-01) meeting, 11-13 April, 2023.
39. Invited Panelist in the Panel discussion by ISRO-HQ on 'Future Exploration of the Inner Solar System: Scope and the Focus Areas' during the National meet to commemorate the occasion of eight years of Indias Mars Orbiter Mission (MOM) on September 27, 2022.
40. Invited Member, AGU Space Physics and Aeronomy Fellows Committee (SPAFC), 2022-2023

Debabrata Banerjee

41. Member, Technical Advisory Committee for Science, Technology and Innovation (STI) Policy Funds, GUJCOST (2022-2025)

Lokesh Kumar Sahu

42. Nodal Faculty for Gujarat, the National Clean Air Programme (NCAP), Ministry of Environment, Forest & Climate Change, since 2019 to Present.
43. Member Expert Group for Gujarat Pollution Control Board (GPCB), peer review of Emission inventory, Source Apportionment Study, and carrying capacity of concerned million-plus cities/non-attainment cities viz. Ahmedabad, Surat, since 2021 to present.

Som Kumar Sharma

44. Associate Editor of the "Journal of Indian Society of Remote Sensing".
45. On review panel of the Indo-French Centre for the Promotion of Advanced Research (IFCPAR/CEFIPRA) projects.

Sanjeev Kumar

46. Associate Editor: Frontiers in Marine Sciences (Marine Biogeochemistry Section) [2016 – present]

Neeraj Rastogi

47. Vice President of Indian Aerosol Science and Technology Association (IASTA), from Jan-2023
48. Editorial Advisory Board, Asian Journal of Atmospheric Environment, from Jan-2020.
49. Nodal Faculty for Gujarat, the National Clean Air Programme (NCAP), Ministry of Environment, Forest & Climate Change, since 2019.
50. Member, Board of Studies Committee for the Space and Atmospheric Science, Centre for Space Science and Technology Education in Asia and the Pacific, (CSSTEAP), United Nations, since 2021.

G. K. Samanta

51. Editorial Board Member, Journal of Optics, IOP
52. Guest Editor, Special Issue on Advances in Optics in India

Jayesh P. Pabari

53. Committee Member, Database of Outside DPC Members of Ph. D. students of GTU, Ahmedabad, 2023.
54. Awarded the International 'Best Raghuvanshi Innovator Award', 2021 by Shri Lohana MahaParishad, 18 June 2022.

Amit Basu Sarbadhikari

55. Section Editor (Mineralogy, Petrology and Geochemistry of the surface of the Moon) for "Encyclopedia of Lunar Science", Springer Publishing

Arvind Singh

56. AGU's diversity, equity, inclusion, and accessibility (DEIA) committee (2022 onwards).
57. Editor: JGR: Oceans (an AGU journal) (July 2021 - present)
58. Scientific Steering Committee member of SOLAS (Surface Ocean Lower Atmosphere Study) (2022-2024)

Ketan M. Patel

59. Selected as Regular Associate of the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy, 2023-2028

Student

Arijit Roy

60. Received Intercat Travel Grant to present his paper "Bottom-up PAH Synthesis via Shocked Carbon Nanodust" at the Life Cycle of Cosmic PAH Conference dated 4-9 September 2022, Aarhus University, Denmark.

Gourav Mitra

61. Received visiting scholar fellowship awarded by the Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) to work at Leibniz Institute of Atmospheric Physics, Germany for 3 months (November 2022 to January 2023).

Subith Kumar

62. Received travel grant award from Optics, USA to present his work at the International Conference on orbital angular momentum (ICOAM-2022) 217 June 2022, Tampere University, Finland.

Sumanjit Chakraborty

63. Young Scientist Award at the 3^{rd} International Union of Radio Science (URSI) Atlantic and Asia Pacific Radio Science (AT-AP-RASC) meeting, May 29 - June 03, 2022, Gran Canaria, Spain.

Sunil Kumar

64. Selected as a SCOSTEP Visiting Scholar (SVS) fellow and visited IAP, Kuhlungsborn, Germany during Sep - Nov 2022.

Yogesh

65. SCOSTEP Visiting Scholar (SVS Fellow) at GSFC NASA, USA, from October 2022 to January 2023.

Recognition, Best paper & Thesis awards

Faculty

Anil Bhardwaj

1. Chairman, Projects Advisory Committee (PAC) for the International Cooperation Programmes of Department of Science and Technology, Govt. of India, July 2022 Present.
2. Member, International Academy of Astronauticss Permanent Committee on Moon Farside Protection, July 2022 Present.
3. Member, Advisory Committee, Cosmic Ray Laboratory of TIFR (DAE), Ooty, 2022 Present.
4. Panel Member, US-India Space Exploration Dialogue on Space Radiation, 2022.
5. Member, LEM (Light Element Mapper) NASA-ESA Mission, Planetary Working Group, 2022 Present.
6. Member, Indian Academy of Sciences, Fellows Sectional Committee for Earth and Planetary Sciences, 20222014.
7. Member, TIFR Balloon Facility Management Board, 2022 Present.
8. Expert Member, Faculty Selection Committee, IISER, Trivandrum, 2022.
9. Member, Selection Committee for IGU-Anni Talwani Memorial Prize for the year 2022.
10. Member, Research Advisory Board, The Maharaja Sayajirao University of Baroda, Vadodara, 2022 Present.
11. Member, Governing Council, Institute of Seismological Research (ISR), Science and Technology Department, Government of Gujarat.
12. Member, Scientific Organising Committee, Session C3.2: "Planetary Upper Atmospheres, Ionospheres and Magnetospheres", 44^{th} COSPAR Scientific Assembly, Athens, Greece, 16-24 July, 2022.

V.K.B. Kota

13. One of the top 2% scientists in the world (and one of the four from PRL) in his field for career-long (till end-of-2021) citations, as announced by Stanford University in 2022.

Srubabati Goswami

14. Member Gender in Physics Working Group of Indian Physics Association, 2023-2024
15. Co-chair, IUPAP International Conference on women in Physics
16. Member, International Advisory committee of the conferences/workshops TAUP 2022,2023, NOW 2022, Neutrino 2022.

Duggirala Pallamraju

17. Member, National Advisory Committee, 2^{nd} One day National conference on, "Advances in Materials Science: Challenges and Opportunities (AMSCO-2023)", 06 March 2023, Department of Physics, Maharaja Krishnakumarsinhji Bhavnagar University, Gujarat, India.
18. Guest Editor, Special issue on the 16^{th} International Symposium on Equatorial Aeronomy (ISEA-16), Earth, Planets and Space (EPS), 2022-2024.
19. Guest Editor, Special issue on SCOSTEP 15^{th} Quadrennial Solar-Terrestrial Physics Symposium (STP-15), Journal of Atmospheric and Solar-Terrestrial Physics 2022-2023.

Nandita Srivastava

20. Member, International Space Weather Initiative (ISWI) Monthly Webinar Series Committee, since April 2022.
21. Reviewer of the Indo-French Centre for the Promotion of Advanced Research (IFCPAR/CEFIPRA) projects.

Varun Sheel

22. Initiated the formation of the Indian Planetary Science Association (IPSA) - Finally Got registered in February 2023 Secretary of IPSA in the founding executive committee.
23. Co-convenor of event B4.2: "Mars Science Results", 44^{th} COSPAR Scientific Assembly, 16-24 July 2022, Athens, Greece.
24. Convenor of session PS08: "Science and Exploration of Mars and Venus",19^{th} annual meeting of the AOGS, Online, 01-05 August 2022.

Sachindra Naik

25. Member, Science Advisory Committee: Aryabhatta Research Institute of Observational Sciences, Nainital.
26. External examiner for Ph.D. thesis submitted to (i) Jamia Millia Islamia University, New Delhi, (ii) Tata Institute of Fundamental Research, Mumbai, (iii) Guru Ghasidas Vishwavidyalaya (A Central University), Bilaspur.

Debabrata Banerjee

27. Reviewer, Indian Antarctic Program (National Center for Polar and Ocean Research), 2022.

D. Chakrabarty

28. Nominated by ISRO for the COSPAR-2022 (Athens, Greece during 16 - 24 July 2022) Organizing Committee in Venus Science and Exploration session, Member, Scientific Organizing Committee (SOC), COSPAR-22-B4.1: Venus Science and Exploration, Invited chair of sessions in C0.3 and C3.2.

Som Kumar Sharma

29. Member of a national committee for technical Review and Realization of the national project; "Atmospheric & Space Research Facility (ASRF)", Balasore, Chandipur, Odisha.
30. Member of a ISRO committee for Technical Review and Realization of the ISRO specific Instruments at Atmospheric & Space Research Facility (ASRF), Balasore, Chandipur, Odisha.
31. Member of Board of Studies (BoS) for the Space and Atmospheric Science (SAS) course, under CSSTEAP (affiliated to UN).
32. Member of Board of Studies (BoS) for the Satellite Meteorology (SATMET) course, under CSSTEAP (affiliated to UN).
33. Nominated for a training programme at Administrative Staff College of India (ASCI), Hyderabad for Training Programme on "Science Administration and Research Management" at ASCI, Hyderabad from September 05-16, 2022.
34. An Expert Member of the BEL (DRDO) Electronics vocabulary augmentation board under CSTT (Ministry of HRD).
35. Expert member of Departmental Promotion Committee (DPC) in DOS/ISRO centres.
36. An Expert Member of the Physics-English-Hindi-Gujarati vocabulary augmentation board under CSTT (Ministry of HRD).
37. Invited as a Chief Guest for DST-INSPIRE programme at Graphic Era University, Dehradun, 29 November, 2022.

N. Rastogi

38. Best poster award for the paper titled "Processes affecting carbonaceous aerosol characteristics over a semi-arid region of western India using dual carbon isotopes" in the first International Symposium on Secondary Aerosol Formation and Growth-2023 (NANO-2023) organized by Finnish Meteorological Institute and Hyderabad Central University held at Hyderabad during March 13-14, 2023.

Shashikiran Ganesh

39. Member of the Steering Committee for Indo Belgium Network in Astronomy
40. SOC member of the third BINA workshop to be organized at ARIES, Nainital, March 22-24, 2023
41. Session chair of Solar system Bodies and Exoplanetary Science session during the 3rd Belgo-Indian Network for Astronomy & Astrophysics (BINA) meeting on the Scientific potential of the Indo-Belgian cooperation, held at Graphic Era Hill University, Bhimtal, 22-24 March 2023.

Bhuwan Joshi

42. Session chair, MHD waves and small-scale transients, 3rd Belgo-Indian Network for Astronomy and Astrophysics (BINA) Workshop, Graphic Era Hill University, Bhimtal, Nainital, 22-24 March 2023
43. Session chair, Sun-Earth connection of solar eruptions, One day workshop on Origin and evolution of solar eruptive phenomena: observations, modeling and Sun-Earth connection, during 41st Astronomical Society of India (ASI) Meeting (ASI-2023) at IIT Indore.
44. Chief Guest, Science Fair-2022, Vidya Bhawan Public School, Udaipur, 30 November 2022

Veeresh Singh

45. Served as an external examiner for M.Phil. thesis defense held at the National Centre for Radio Astrophysics - Tata Institute of Fundamental Research (TIFR) Mumbai, 27 January 2023.

Shanmugam M.

46. Co-chair of a session in 21st National Space Science Symposium 2022, PS-3: Solar and planetary sciences.
47. Member of Scientific Organizing Committee (SOC) for the workshop conducted by SPL/VSSC on Science from In-Situ Measurements of Aditya-L1 (SIMA-01), 11-13, April, 2023.
48. Nominated to attend the Management Development Programme (MDP) conducted to Administrative Staff College of India (ASCI), Hyderabad for ISRO Scientists/Engineers, 05-16, December 2022.

Jayesh P. Pabari

49. Co-convener, AOGS Session on Lunar Volatiles (PS11), 1-5 August 2022

Dwijesh Ray

50. Paper entitled A petrographic and electron microscopic evaluation of Carbonaceous Chondrite: LON 94101 was the recipient of one of the best posters awards in 4^{th} IPSC 2023 to be held at March 22-24.

Neeraj Srivastava

51. Panel Member, Future Exploration of the Inner Solar System: Scope and the Focus Areas, National meet to commemorate the occasion of eight years of Indias Mars Orbiter Mission (MOM), ISRO HQ, September 27, 2022.

52. Member, Task Team to identify the Landing Site for Mars Landing Mission, ISRO.

53. External Examiner, M. Sc. Geology Practical examination, MG Science Institute, Gujarat University, 13^{th} Dec. 2022.

Amitava Guharay

54. Serving as a topic editor for the special issue “Advances in Mesosphere and Thermosphere Dynamics” since 24/02/2023 of the journal, Frontiers in Astronomy and Space Sciences.

Narendra Ojha

55. Session Chair, COFSAS-2023, 15-16 March 2023. (virtual)

Ravindra Pratap Singh

56. Foreign Visiting Cooperation Researcher, Nagoya University, Japan, 12 Oct 2022 to 15 Nov 2022.

Girjesh R Gupta

57. External Examiner: Dr. Satabdwa Majumdar (PDF interview 2022, ARIES).

58. SOC Member, 3rd Aditya-L1 Support Cell Workshop, 25-27 Feb 2023, IIT BHU, Varanasi.

K. Venkatesh

59. Selected as one of the top ten most valued reviewers of the journal Advances in Space Research for the year 2022.

60. Selected as one of the Excellent Reviewers of the journal “Earth, Planets and Space” for the year 2022.

61. Taking part as a guest editor in ASR for a special issue on Mesosphere-Thermosphere-Ionosphere Studies, which is in connection with the C1.1 session of COSPAR-2022.

Lokesh Kumar Dewangan

62. SOC member of the the conference on Star Formation Studies in the Context of NIR instruments on 3.6 m DOT at ARIES, Nainital, May 4-7, 2022

63. Member of the Formation of Stars and Planets International Science Development Team (ISDT) of the Thirty Meter Telescope (TMT).

Vijayan S.

64. Vijayan et al., 2022, Boulder fall ejecta: present day activity on Mars, GRL is one of the most downloaded article from GRL journal.

Megha Bhatt

65. Core team member of inaugral Forming and Exploring Habitable Worlds International meeting, 7-13 November, 2022 held at Edinburgh, UK.

66. Elected as Main Scientific Organizer (MSO) of the session Lunar Science and Exploration for COSPAR 2024.

67. Vice-Chair of Sub-Commission B3, COSPAR, for the period 2021-2024.

68. Session chair Forming and Exploring Habitable Worlds International meeting, 7-13 November, 2022, Edinburgh, UK

69. Session chair COSPAR 2022 44^{th} Scientific Assembly, 16-24 July 2022, Athens, Greece.

Shiv Kumar Goyal

70. Selected as Fellow member (life time) of The Institution of Electronics & Telecommunication Engineers (IETE)

Dinesh Mehta

71. Member of Local Organizing committee (LOC), Venus Science Conference (Venus-SC-2022), PRL, Ahmedabad, 29-30 September 2022

Sneha Nair

72. Selected for the popular quiz show "Kaun Banega Crorepati Season-14" and reached to the Hot Seat alongside Shri Amitabh Bachchan. Represented PRL (DOS) and its activities on National Television. [Sept 2022]
73. Received 2^{nd} prize in the State Level Hindi Essay writing competition organized by PRL and TOLIC, Ahmedabad. [August 2022]

Student

Akanksha Arora

74. Akanksha won the first prize for Best Oral Presentation in NoBLExClim (National Workshop on Boundary Layer Exchange Processes and Climate Change) 23-24 March 2023, Chennai jointly organized by MoES, SERB and SRM Institute of Science and Technology.

Mansi Gupta

75. Best poster presentation award for the paper titled "Spatio-temporal variation and relationship between air-sea exchanges of DMS and VOCs over the northern Indian Ocean during post-monsoon season" at the Surface Ocean-Lower Atmosphere Study (SOLAS)-Open Science Conference (OSC)-2022 held in Cape Town, South Africa, during 25-29 September 2022.
76. Joint Secretary of the Early Career Scientist Network of International Indian Ocean Expedition-2 (IIOE-2-ECSN) from March 2022 to present.

Meghna Soni

77. 2^{nd} Prize in the Students Paper competition, URSI Regional Conference on Radio Science (URSI-RCRS), IIT-Indore, India, 1-4 December, 2022.
78. Early Career Best Oral Presentation Award, 17^{th} IGAC Science Conference, Manchester, UK and virtually everywhere, September 10-15, 2022.

Neeraj Kumari

79. SOC member of the Young Astronomers' Meet (YAM) 2022, ARIES, Nainital, India, 9-13 November, 2022

Human Resource Development

Human Resource Development at PRL

PRL has a strong Human Resource Development (HRD) component with Research Fellowship programme leading to PhD degree, Post-Doctoral and Visiting Scientist programs. In addition, we have an Associate program for university teachers and project training for graduate and post graduate students in both science and engineering. PRL hosts science and engineering disciplines students for their project training as a part of their curriculum. The purpose is to provide the students with an insight into current research activities being pursued at PRL which they can continue even after returning to their colleges/universities/institutes. It is also aimed at motivating them to take up research in basic sciences in their higher studies and career. Brief details of scientific output and staff in numbers during the reporting year are provided here.

Research Fellowship Programmes

One of the important aims of the laboratory is to serve as a post-graduate and post-doctoral study centre in Physics, Earth & Planetary sciences and Chemistry to train research scholars in various aspects of experimental and theoretical research. With this in view, PRL offers a research fellowshop programme leading to Ph. D. degree. PRL provides opportunities for carrying out post-doctoral research. The strength of fellows under these programmes are presented in figure 1.

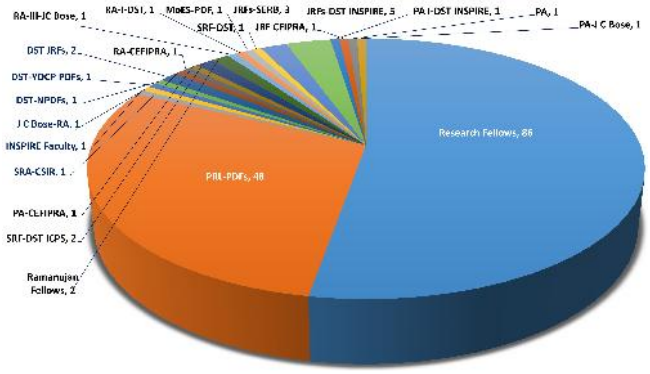


Figure 1: Research Programmes.

Research Programmes through Externally funded schemes

PRL encourages candidates with external funding from Government agencies such as DST, CSIR, NBHM, UGC, ISRO RESPOND, etc., to carry out their research in all campuses of PRL. Such candidates are governed by fellowship rules of the concerned funding agencies as applicable from time to time. Such candidates have an option to register for a Ph.D. degree in any of the institutes/universities with which PRL has an MoU, subject to their fulfilling the required eligibility criteria and course work requirements of the concerned university/Institute. Following table summarize the ongoing externally funded projects in PRL and figure 1 give statistics of the Research Scholars/PDFs/RAs in PRL including the ones employed through the externally funded projects.

Training Opportunities

PRL provides project training in engineering disciplines like computer engineering, electronics & communication, instrumentation & control, information technology to graduate/post-graduate students. Details of the same are presented in figure 2.

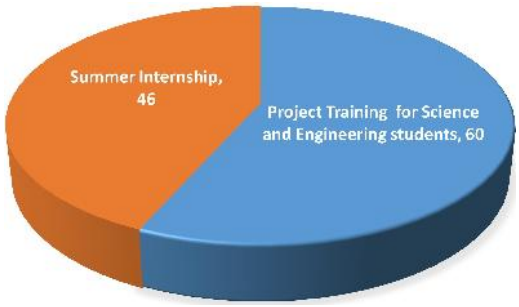


Figure 2: Internship Training Programmes.

PRL also offers training programmes in computers, electronics, library science, engineering and administrative services (Fig. 3).

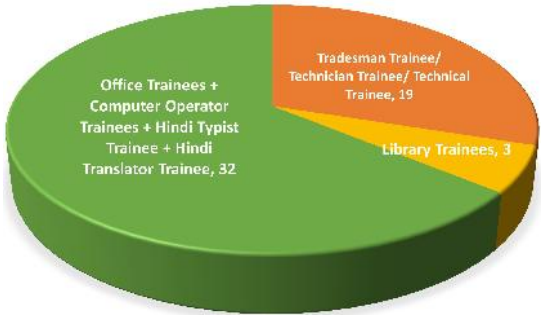


Figure 3: Training Programmes in technical and administrative areas.

Research Contributions

The research work carried out by PRL scientists are published in reputed and peer reviewed national and international journals. Several of our scientists are also invited to write review articles in the field of their specialization. Some of our scientists have also edited books.

Many of our scientists attended conferences and symposia at home and abroad where they present the results of their research investigations. Some of them are invited to present review talks. Few of them serve as chairpersons and Members of scientific committees for organizing national and International conferences and symposia. They are also invited to Convene and Chair sessions during symposia and meetings. The research output during the AY 2022-23 is shown in figure 4.

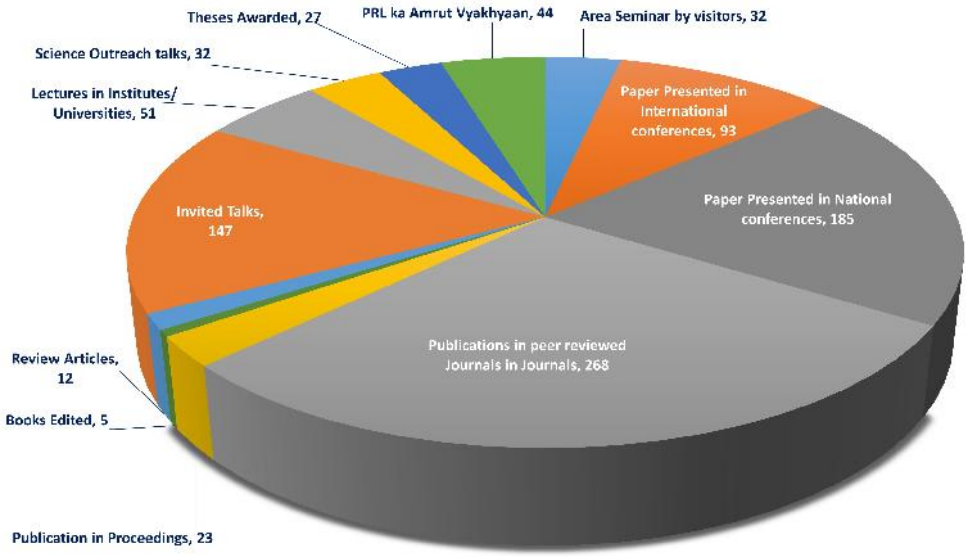


Figure 4: Research Contributions.

Administrative Support

Behind the scientific achievements of PRL is the able and efficient support given by the administrative and the technical staff. The administrative section of our laboratory continues to play an important role in providing an excellent management support to carry out our scientific activities. In addition, it also provides management support to the Solar Observatory at Udaipur and the Infrared Observatory al Mt. Abu. The staff structure of PRL is shown in figure 5.

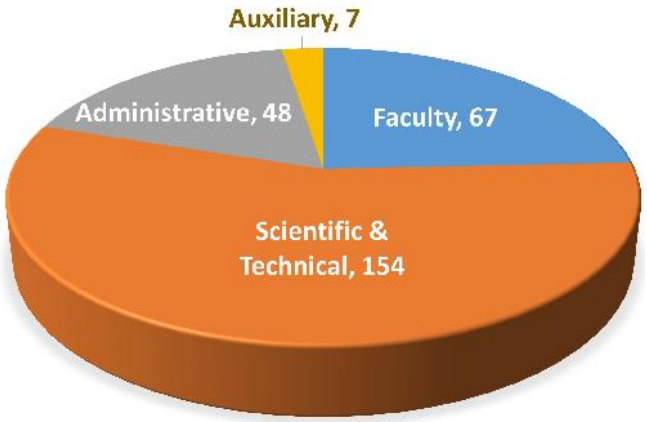


Figure 5: The distribution of PRL staff.

Status of Scheduled Caste/ Scheduled Tribe Personnel as on 31/03/2023

Centre/ Unit	Total Strength of Employees 2022-23	Strength of SC Employees	Strength of ST Employees	Strength of OBC Employees
PRL	276	12	08	54

Status of Differently Abled persons as on 31/03/2023

Centre/ Unit	Total Strength of Employees	Strength of Differently Abled Persons	Classification of employees with Disabilities			
			Deaf and Dumb	Blind	Partially Blind	Orthopedically Handicapped
PRL	276	5	1	0	0	4

Research Fellowship Programme and Pre-PhD courses

PRL offers Junior Research Fellowships (JRFs) leading to a Ph.D. degree in the broad areas of ongoing research activities in PRL. Since inception of PRL around 480 research scholars have obtained their Ph.D. degree. PRL alumni have played a key role in the development of institutions and programmes in India and abroad. The Indian Space Research Organization (ISRO) was nucleated in PRL in the early seventies and two of the past ISRO Chairmen, Prof. U.R. Rao and Prof. K. Kasturirangan - are distinguished alumni of PRL.

After admission to PRL, each JRF needs to undergo a prescribed pre-Ph.D. course work prior to joining the research. In consideration of the requirements of (a) various Universities / IIT, where PRL research scholars register for their Ph.D. degree, and (b) University Grants Commission guidelines, two semesters of rigorous course work is offered to JRFs. In addition, JRFs are also required to do four projects as a part of their course work. In the year 2022-23, 14 new JRFs have joined PRL and 27 SRFs have been awarded Ph.D. degree.

Following is the list of courses offered to Junior Research Fellow of 2022 batch. Each course is of four credits and 40 hours of teaching.

Semester 1 courses

1. Research Methodology-[Instructors: Dr. Naveen Chauhan & Dr. Narendra Ojha]
2. Fundamental Astronomy-[Instructors: Dr. Manash Samal & Dr. Vishal Joshi]
3. Solid State Physics-[Instructors: Dr. Debi Prasad Panda & Dr. Satyendra Nath Gupta]
4. Isotope Geochemistry (IG)-[Instructors: Dr. Vineet Goswami]
5. Stable Isotopes in Nature (SIN)-[Instructors: Dr. Amzad H Laskar]
6. Basics of Planetary Geology-[Instructors: Dr. S. Vijayan & Dr. Neeraj Srivastava]
7. Solar System: Formation and Processes-[Instructors: Dr. Kinsuk Acharyya & Dr. Jayesh Pabari]
8. Physics of near-Earth Space-[Instructors: Dr. K. Venkatesh]
9. Fundamentals of Earth's Atmosphere-[Instructors: Dr. Lokesh Kumar Sahu & Dr. Som Kumar Sharma]
10. Advanced Quantum Mechanics-[Instructors: Dr. Navinder Singh]
11. Quantum Field Theory - II-[Instructors: Dr. Namit Mahajan]
12. Particle Physics-[Instructors: Dr. Partha Konar]
13. Atmospheric, Aquatic, and Terrestrial Biogeochemistry-[Instructors: Dr. Sanjeev Kumar & Dr. Neeraj Rastogi]
14. Advanced Remote Sensing Geology-[Instructors: Dr. Megha Upendra Bhatt & Mr. Rishitosh Kumar Sinha]
15. Cosmochemistry-[Instructors: Mr. R R Mahajan]
16. Dynamical, chemical and coupling processes in the Earths atmosphere-[Instructors: Dr. Amitava Guharay]

Semester 2 courses

17. Earth Surface Processes and Quaternary landform evolution-[Instructors: Shubhra Sharma]
18. Experimental Laser Spectroscopy-[Instructors: Dr. Rajesh Kumar Kushawaha]
19. Instrumentation in Geosciences-[Instructors: Dr. Anil Shukla & Dr. A K Sudheer]
20. Ionosphere Thermosphere Processes and Measurement Techniques-[Instructors: Dr. K. Venkatesh]
21. Lower atmospheric measurements and analysis techniques-[Instructors: Dr. T. A. Rajesh & Dr. Lokesh Sahu]
22. MLT processes and optical Instrumentation-[Instructors: Dr. Ravindra Pratap Singh]
23. Molecular spectroscopy-[Instructors: Dr. Dipen Sahu & Dr. Bhalamurugan Sivaraman]
24. Non-traditional Isotopes in Geosciences (NIG)-[Instructors: Dr. Yogita Kadlag]
25. Physicochemical processes of trace gases-[Instructors: Dr. N. Ojha]
26. Quantum Optics-[Instructors: Dr. RP Singh & Dr. Shashi Prabhakar]
27. Solar system objects-[Instructors: Dr. Shashikiran Ganesh]
28. Star formation-[Instructors: Dr. Lokesh Kumar Dewangan]
29. Theoretical Atomic Physics-[Instructors: Dr. Bijaya Kumar Sahoo]

List of projects done by JRF of 2022 batch are as follows:

Akash Sundriyal

1. “Searching For Coherent Periodicity In The Tess Light Curves Of Two Cataclysmic Variable Candidates”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Vishal Joshi, Division: Astronomy and Astrophysics].
2. “Understanding Quantum Key Distribution And Its Practical Implementations”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Prof. R.P. Singh, Division: Atomic, Molecular and Optical Physics].

Aakash Gupta

3. “Velocity Distribution Function of Ions in Solar Wind”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Prof. Dibyendu Chakrabarty, Division: Space, Atmospheric, Molecular and Laser Physics].
4. “Latitudinal and Longitudinal Response of the Ionospheric Total Electron Content (TEC) During Intense Solar Flares”, Semester 2 project, from January 2023 to May 2023, [Supervisior: Dr. K. Venkatesh, Division: Space, Atmospheric, Molecular and Laser Physics].

Aarti Yadav

5. “Populating the periodic table: Nucleosynthesis of the elements”, Semester 1 project, from May 2022 to July 2022, [Supervisior: Dr. Kinsuk Acharyya, Division: Planetary Sciences].
6. “Study of hypervelocity impacts on spacecrafts”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Dr. Jayesh P. Pabari, Division: Planetary Sciences].

Akash Ganguly

7. “Resolving the controls of meteorology on stable water isotopes of Precipitation:A Machine Learning Approach”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Prof. R. D. Deshpande, Division: Geosciences].
8. “Resolving the meteorological controls governing fine-particulate matter in the Indo-Gangetic Plain using Machine Learning”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Prof. Narendra Ojha, Division: Space, Atmospheric, Molecular and Laser Physics].
9. “The world of LIDARS: Insights from Ceilometer observations over Western Himalayas at LEH, India”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Prof. Som Kumar Sharma, Division: Space, Atmospheric, Molecular and Laser Physics].
10. “Predicting Ground Water Level in Gujarat using Machine-Learning and Remote Sensing”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Prof. R.D. Deshpande, Division: Geosciences].

Arijit Maiti

11. “Photometric and Spectroscopic studies of the Nova V6595 Sgr”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Mudit K. Srivastava, Division: Astronomy and Astrophysics].
12. “Monte Carlo Simulation to simulate Lunar water migration”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Kinsuk Acharyya, Division: Planetary Sciences].
13. “Studies of the designs of IFUs for astronomy”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Dr. Mudit K. Srivastava, Division: Astronomy and Astrophysics].

Ashish Kumar Mandal

14. “Structure And Evolution Of Stars.”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Manash Samal, Division: Astronomy and Astrophysics].
15. “Optical spectrographs for aeronomy study”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Prof. D. Pallamraju, Division: Space, Atmospheric, Molecular and Laser Physics].
16. “Semiconductor drift detector”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Prof. Santosh Vadawale, Division: Astronomy and Astrophysics].

Chahat Kaushik

17. “Geometric Phase in Optics”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. G. K. Samanta, Division: Atomic, Molecular and Optical Physics].
18. “Detection of Charged Particles in Radiation Detectors”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. M. Shanmugam, Division: Planetary Sciences].
19. “Study of Ionized emission in H-II regions”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Dr. Lokesh Dewangan, Division: Astronomy and Astrophysics].

Deepanshu Srivastava

20. “Presolar Grains”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Kuljeet Kaur Marhas, Division: Planetary Sciences].
21. “Gravity as an Effective Field Theory”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Namit Mahajan, Division: Theoretical Physics].

Dibyendu Misra

22. “Geological Significance for the occurrence of OH/H20 in the Clavius Crater Region”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Dr. Megha U. Bhatt, Division: Planetary Sciences].
23. “Correlation between hydration feature on the Lunar surface at 3 and 6 m spectral range using the derived results from the M3 and telescopic data”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Dr. Megha U. Bhatt, Division: Planetary Sciences].

Goldy Ahuja

24. “An introduction to Turbulence using Correlation Tensor”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Aveek Sarkar, Division: Astronomy and Astrophysics].
25. “An introduction to the Physics Based Deep Learning”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Prof. Partha Konar, Division: Theoretical Physics].

Harithasree S

26. “Application of Machine Learning for Ozone Prediction”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr, Narendra Ojha, Division: Space, Atmospheric, Molecular and Laser Physics].
27. “Changing Seawater Carbonate Chemistry over the Sargasso Sea in North Atlantic Ocean”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Arvind Singh, Division: Geosciences].

Indrajit Kabiraj

28. “A study on spectral phase interferometry for direct electric field reconstruction”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Rajesh Kumar Kushawaha, Division: Atomic, Molecular and Optical Physics].
29. “A study on Soil organic carbon dynamics in tropical Indian soils”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Amzad Hussain Laskar, Division: Geosciences].

Janaarthanan P A

30. “Stable isotope and trace element analysis of Bora cave speleothems”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Dr. Amzad Hussain Laskar, Division: Geosciences].
31. “Laser Fluorination System for measurements of isotopic composition of silicates”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Prof. Sanjeev Kumar, Division: Geosciences].

Kiran

32. “Characterizing Extinction Coefficient of Devasthal Astronomical Site”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Manash Samal, Division: Astronomy and Astrophysics].
33. “Grating based Imaging Spectrograph for OH and O 2 intensity and temperature measurements”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Ravindra Pratap Singh, Division: Atomic, Molecular and Optical Physics].

Komal

34. “The velocity distribution function of electrons in solar wind”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Dr. Dibyendu Chakrabarty, Division: Space, Atmospheric, Molecular and Laser Physics].

Mehul Sompura

35. “Astronomical Photometry Using Python”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Dr. Vishal Joshi, Division: Astronomy and Astrophysics].
36. “Numerical Simulation of two-stream instability”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Dr. Aveek Sarkar, Division: Astronomy and Astrophysics].

Narendranath Layek

37. “Variability Of Blazars”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Shashikiran Ganesh, Division: Astronomy and Astrophysics].
38. “Structure And Evolution Of Stars”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Kinsuk Acharyya, Division: Planetary Sciences].

Neeraj

39. “Solar Wind Power Spectrum”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Dr. Aveek Sarkar, Division: Astronomy and Astrophysics].
40. “SED Modeling of a Star: Deriving the Spectral type”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Dr. Vishal Joshi, Division: Astronomy and Astrophysics].

Neeraj Tiwari

41. “Moments of Plasma Velocity Distributions (ASPEX: SWIS)”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Prof. Dibyendu Chakrabarty, Division: Space, Atmospheric, Molecular and Laser Physics].
42. “Poissonian Statistics of Astronomical X-ray Sources”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Prof. R. P. Singh, Division: Atomic, Molecular and Optical Physics].
43. “Study of an AGN: UGC6728, by analysing ASTROSAT data”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Prof. Sachindra Naik, Division: Astronomy and Astrophysics].
44. “Study of an open cluster: NGC2682”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Dr. Manash Samal., Division: Space, Atmospheric, Molecular and Laser Physics].

Nitinkumar Ladhv

45. “Method Of Integrate Chromatographic Peaks For Vocs Analysis”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Dr. Loksesh Sahu, Division: Space, Atmospheric, Molecular and Laser Physics].
46. “Study of Clouds and Precipitation over Ahmedabad”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Prof. Som Kumar Sharma, Division: Space, Atmospheric, Molecular and Laser Physics].

Omkar Ratan Jadhav

47. “Studying the nature of Ionized emission in H-II regions”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Dr. Lokesh Kumar Dewangan, Division: Astronomy and Astrophysics].
48. “Multi-wavelength study of region G47.06 +0.26”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Dr. Lokesh Kumar Dewangan, Division: Astronomy and Astrophysics].

Rachita Nandan

49. “Studying the OAM States of Light”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Dr. Shashi Prabhakar, Division: Atomic, Molecular and Optical Physics].
50. “Light Scattering by Plasmonic Antennas and its coupling with Quantum Dots”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Dr. Satyendra Nath Gupta, Division: Atomic, Molecular and Optical Physics].

Rahul Kumar Agrawal

51. “Use of Stable isotopes in ecological studies”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Amzad Hussain Laskar, Division: Geosciences].
52. “Phytovolatilization and Phytodegradation of soil Volatile organic compounds Sustainable detoxification techniques”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Lokesh Kumar Sahu, Division: Space, Atmospheric, Molecular and Laser Physics].

Ravi Chaurasiya

53. “A study of flare associated changes in the active region NOAA 12994 using observation from MAST and SDO/HMI.”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Ankala Raja Bayanna, Division: Solar Physics].
54. “Characterization of Solar Energetic particles (SEP) from 1 AU”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Prof. Dibyendu Chakrabarty, Division: Space, Atmospheric, Molecular and Laser Physics].

Sahil Rathi

55. “Controlling the radiative properties of quantum emitters”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Dr. Satyendra Nath Gupta, Division: Atomic, Molecular and Optical Physics].
56. “Free space propagation of LG open vortex beam”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Dr. Shashi Prabhakar, Division: Atomic, Molecular and Optical Physics].

Sandeep Kumar Dubey

57. “Automation Of MFOSC-P Data Reduction”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. M. K. Srivastava, Division: Astronomy and Astrophysics].
58. “Modelling Instrument Polarization Of Mast Telescope”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Prof. Shibu K Mathew, Division: Solar Physics].

Sandip Bhattacharyya

59. “Characteristics of dominant atmospheric tides during September 2019 over Ahmedabad”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Dr. Amitava Guharay, Division: Space, Atmospheric, Molecular and Laser Physics].
60. “Unusual variations of Ionospheric Total Electron Content (TEC) over Ahmedabad”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Dr. K. Venkatesh, Division: Space, Atmospheric, Molecular and Laser Physics].

Satyandra M. Sharma

61. “Physics of the Martian Boundary Layer”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Prof. Varun Sheel, Division: Planetary Sciences].
62. “Excitation of precursor solitons from moving object in a plasma”, Semester 2 project, from January 2023 to May 2023, [Supervisior: Dr. Sanjay K. Mishra, Division: Planetary Sciences].

Shreya Mehta

63. “Study of distribution and abundance of Trichodesmium based on abiotic parameters”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr Arvind Singh, Division: Geosciences].
64. “Salinity in Atlantic and Pacific Oceans and its implication towards the oceanic processes”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr Narendra Ojha, Division: Space, Atmospheric, Molecular and Laser Physics].

Shubhendra Nath Das

65. “Obtaining basic parameters of exoplanet using transit method”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Dr. Abhijit Chakraborty, Division: Astronomy and Astrophysics].
66. “SIRIUS data reduction and comparison with 2MASS data for the LN45-1G target”, Semester 1 project, from January 2023 to April 2023, [Supervisior: Prof. Shashikiran Ganesh, Division: Astronomy and Astrophysics].

Soumik Kar

67. “Turbulence in Arsia Mons region of Mars and importance of bulk Richardson Number”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Prof. Varun Sheel, Division: Planetary Sciences].
68. “An overview of Planet formation”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Kinsuk Acharyya, Division: Planetary Sciences].

Tanya Srivastava

69. “Mineralogy of Gale and Jezero Crater”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Dr. Vijayan S, Division: Planetary Sciences].

Tatsat Hirenkumar Solanki

70. “In search of paleo-analogs of Ocean Alkalinity Enhancement”, Semester 1 project, from August 2022 to December 2022, [Supervisior: Dr. Arvind Singh, Division: Geosciences].
71. “Trace Elements in the Ocean”, Semester 2 project, from January 2023 to April 2023, [Supervisior: Dr. A K Sudheer, Division: Geosciences].

Varsha M Nair

72. “Multi-Angular Reflectance Spectroscopy Of Lohawat Meteorite .”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Neeraj Srivastava, Division: Planetary Sciences].
73. “Mineralogy Of Lohawat Meteorites”, Semester 2 project, from May 2022 to July 2022, [Supervisior: Dr. Anil D Shukla, Division: Geosciences].

Ph.D. Awarded

[PRL students/project associates/employees]

Nisha Bharti

1. “Quaternary ventilation of the Indian Ocean deep basins, foraminiferal isotopic and abundance approach”, Indian Institute of Technology, Gandhinagar, 23-05-2022, [Supervisor: Ravi Bhushan].

Ayan Biswas

2. “Free Space Quantum Key Distribution: Experiments for Improving Security and Key Rate”, Indian Institute of Technology, Gandhinagar, 18-07-2022, [Supervisor: R. P. Singh].

Ramanuj Mitra

3. “Application of Relativistic Coupled-Cluster Method to Study P, T-odd Properties in Heavy and Superheavy Molecules”, Indian Institute of Technology, Gandhinagar, 30-07-2022, [Supervisor: Bijaya Kumar Sahoo].

Rasma, K. (External Student)

4. “Air Quality Assessment Approaches Using Multi-sensory Data at Local and Regional Scales”, Indian Institute of Technology, Bombay, 20-08-2022, [Supervisor: Harish Gadhavi (Co-Supervisor)].

Abdur Rahman

5. “Paleoenvironment reconstruction of the Himalayan region using stable isotopes in lake sediments”, Pondicherry University, 22-08-2022, [Supervisor: Sanjeev Kumar].

Tanmay Kumar Poddar

6. “Enlightening the dark universe through light particles”, Indian Institute of Technology, Gandhinagar, 01-09-2022, [Supervisor: Srubabati Goswami].

Vishal Singh Ngairangbam

7. “Searching for new physics signatures in hadronic final states at the Large Hadron Collider with deep learning”, Indian Institute of Technology, Gandhinagar, 12-09-2022, [Supervisor: Partha Konar].

Prabir Mitra

8. “Investigations of Initiation and Evolution of Transient phenomena in Solar Atmosphere”, Gujarat University, 27-09-2022, [Supervisor: Bhuwan Joshi].

Neeraj Kumari

9. “Multi-wavelength studies of Active Galactic Nuclei”, Indian Institute of Technology, Gandhinagar, 21-11-2022, [Supervisor: Sachindranatha Naik].

Sarika Mishra

10. “Entangled Photons and Their Applications in Quantum Information Processing”, Indian Institute of Technology, Gandhinagar, 16-12-2022, [Supervisor: R. P. Singh].

Partha Sarathi Jena

11. “Applications of cosmogenic nuclides in understanding Quaternary events”, Indian Institute of Technology, Gandhinagar, 22-12-2022, [Supervisor: Ravi Bhushan].

Sudipta Show

12. “Phenomenological implication of particle dark matter models”, Indian Institute of Technology, Gandhinagar, 29-12-2022, [Supervisor: Partha Konar].

Alka Rani

13. “Geological and Geochemical Study of Martian Volcanic Provinces: Implications for Igneous Evolution of Mars”, Indian Institute of Technology, Gandhinagar, 10-01-2023, [Supervisor: Amit Basu Sarbhadhikari].

K. B. Smart (External Student)

14. “Photon and Charged-particle Interaction with Surface of the Europa”, Cochin University of Science and Technology, Kochi, 10-01-2023, [Supervisor: Anil Bhardwaj].

Sushant Dutta

15. “Evolution of remnant radio galaxies”, Indian Institute of Technology, Gandhinagar, 18-01-2023, [Supervisor: Veeresh Singh].

Kamlesh Bora

16. “On the role of Hall magnetohydrodynamics in magnetic reconnection: Astrophysical Plasmas”, Indian Institute of Technology, Gandhinagar, 23-01-2023, [Supervisor: Ramitendranath Bhattacharyya].

Anshika Bansal

17. “Phenomenological Applications of Light Cone Sum Rules”, Indian Institute of Technology, Gandhinagar, 03-02-2023, [Supervisor: Namit Mahajan].

Himanshu Saxena

18. “Biological fixation of nitrogen and carbon in the northern Indian Oceans”, Indian Institute of Technology, Gandhinagar, 08-02-2023, [Supervisor: Arvind Singh].

Ankit Kumar

19. “Investigations on Low Latitude Ionosphere under Varying Space Weather Conditions”, Indian Institute of Technology, Gandhinagar, 17-02-2023, [Supervisor: Dibyendu Chakrabarty].

Biswajit Mondal

20. “Investigating the coronal X-ray characteristics - From Sun as a star to imaging spectroscopy”, Indian Institute of Technology, Gandhinagar, 20-02-2023, [Supervisor: Santosh V. Vadawale].

Suvadip Sinha

21. “Investigating solar drivers of space weather”, Indian Institutes of Science Education and Research, Kolkata, 20-02-2023, [Supervisor: Co-supervisor: Prof. Nandita Srivastava].

Sovan Saha

22. “Investigations of Low- and Equatorial-Latitude Upper Atmospheric Processes using Optical and Radio Techniques”, Indian Institute of Technology, Gandhinagar, 21-02-2023, [Supervisor: Duggirala Pallamraju].

Suraj Sahu

23. “Eruption of Solar Magnetic Flux Ropes and Associated Flaring Activity: Observational Perspectives”, Indian Institute of Technology, Gandhinagar, 22-02-2023, [Supervisor: Bhuwan Joshi].

Hirdesh Kumar

24. “Study of the Evolution of Velocity and Magnetic Fields in the Solar Atmosphere”, Indian Institute of Technology, Gandhinagar, 13-03-2023, [Supervisor: Brajesh Kumar].

Satyajeet Patil

25. “Orbital Angular Momentum of Light and Quantum Correlations”, Indian Institute of Technology, Gandhinagar, 14-03-2023, [Supervisor: R. P. Singh].

Vipin Kumar

26. “Aspects of Spectroscopic and Polarimetric Instrumentation for Ground Based Optical Telescopes with related Observations”, Indian Institute of Technology, Gandhinagar, 28-03-2023, [Supervisor: Mudit K. Srivastava].

Rituparna Das

27. “Interaction of intense femtosecond pulses with polyatomic molecules: probing the ultrafast dynamics”, Indian Institute of Technology, Gandhinagar, 01-06-2023, [Supervisor: Rajesh Kumar Kushawaha].

Special Talks & PRL ka Amrut Vyakhyaan

Dr. Bibha Chowdhuri Memorial Lecture

- Prof. Rama Govindarajan
  International Centre for Theoretical Sciences, Bengaluru
  Dynamics of small particles in flow 07 March 2023

PRL-IAPT Dr. Vikram Sarabhai Lecture

- Prof. D. Pallamraju
  Physical Research Laboratory, Ahmedabad
  Space Research Through Optical Window 22 March 2023

Dr. Arvind Bhatnagar Memorial Lecture

- Prof. Arnab Rai Choudhuri
  Indian Institute of Science, Bangalore
  An enigmatic fluid flow inside the Sun: the Meridional Circulation 16 November 2022

PRL ka Amrut Vyakhyaan

1. Shri Kumar Keshav
   Managing Director, Uttar Pradesh Metro Rail Corporation
   Uttar Pradesh Metro: Building Modern Urban Transport Systems for the Changing Needs of the Cities: Challenges and Lessons Learnt 06 April 2022
2. Prof. Lisa Jennifer Kewley
   Australian National University, Australia
   ASTRO 3D 13 April 2022
3. Prof. A R Ravishankara
   University of Colorado, Boulder
   The ozone layer, its science, and its policies 20 April 2022
4. Dr. R. Krishnan
   Indian Institute of Tropical Meteorology, Pune
   Predictive understanding of the Indian monsoon in a changing climate 27 April 2022
5. Prof. Pierre Cox
   Director of research, CNRS, Institut d'Astrophysique de Paris IAP, France
   The Cold Universe: A Journey to our Cosmic Origins 04 May 2022
6. Prof. Ada Yonath
   Director, Helen and Milton A. Kimmelman Center for Biomolecular Structure and Assembly of the Weizmann Institute of Science, Israel
   Next Generation Species Specific and Eco Friendly Antibiotics and thoughts about the origin of life 11 May 2022
7. Prof. Philip R. Christensen
   Regents' Professor, Geological Sciences, Ed and Helen Korrick Professor, School of Earth and Space Exploration Arizona State University, USA
   Infrared eyes: Exploring the solar system using infrared instruments 18 May 2022
8. Dr. Parthiv Mehta
   U N Mehta Institute of Cardiology, Mehta Hospital & Cardiopulmonary Care Centre, Central United Hospital, Ahmedabad, Gujarat, INDIA
   Living Beyond 100 Years - Myth or Truth? 25 May 2022
9. Prof. Dmitry Budker
   Helmholtz Institute, Johannes Gutenberg University Mainz, Mainz, Germany and Professor of Graduate School, University of California at Berkeley, USA
   Hunting elephants in a room: new ways to search for dark matter and other adventures 01 June 2022
10. Dr. (Mrs.) Vandana Prasad
    Birbal Sahni Institute of Palaeosciences, Lucknow
    Role of Plate Tectonics and Climate in the Evolution of Tropical Angiosperms: Evidence from Indian Fossil Records 08 June 2022
11. Prof. Guy Brasseur
    Max Planck Institute for Meteorology, Hamburg, Germany and National Center for Atmospheric Research, Boulder, CO
    A Historical Journey to Discover the Mysteries of Air 15 June 2022
12. Shri Atul Karwal, IPS
    National Disaster Response Force and, Director, SVP National Police Academy Hyderabad
    Explore and Learn 22 June 2022
13. Dr. Raman R. Gangakhedkar
    Indian Council of Medical Research
    COVID 19 in India - Opportunities & Challenges 29 June 2022
14. Prof. Shubha Tole,
    Department of Biological Sciences, Tata Institute of Fundamental Research, Mumbai
    The Circuits of Sensation: How We Perceive the World 06 July 2022
15. Shri Vishnu Pandya
    Gujarat Sahitya Academy, Govt. of Gujarat, Ahmedabad
    My Language, My Country (*Meri Bhasha, Mera Desh*) 13 July 2022

16. Mr. Luis Miranda
Chairman of the Board & Co-Founder Indian School of Public Policy
Luck and Networking - how they can help you 20 July 2022

17. Prof. Yashwant Gupta
National Centre for Radio Astrophysics, Pune
Probing the Universe with radio waves : landmark achievements in India over the years 27 July 2022

18. Prof. Ajoy Ghatak
The National Academy of Sciences India, Prayagraj & Optics & Photonics Centre, IIT Delhi
EVOLUTION OF QUANTUM THEORY & A SIMPLE DERIVATION OF BELLS INEQUALITY 03 August 2022

19. Mr. Kartikeya Sarabhai
Centre for Environment Education, Ahmedabad
Science and the Challenges of Climate Chang 10 August 2022

20. Prof. Anil Gupta
Honey Bee Network, SRISTI, GIAN & NIF, Indian Institute of Management, Ahmedabad & IITB, AcSIR
Leadership in bridging inclusive science and creative society: lessons for learners 17 August 2022

21. Dr. Sumer Chopra
Institute of Seismological Research, Gandhinagar
Seismological Research and Gujarats Initiative 24 August 2022

22. Prof. Michel Danino
Humanities and Social Sciences, IIT Gandhinagar
The Sarasvati River and the Indus civilization 31 August 2022

23. Dr. Shailesh Nayak
National Institute of Advanced Studies, Bengaluru
From Ocean Science to Blue Economy 07 September 2022

24. Prof. Michel Mayor
University of Geneva, Switzerland
Other Worlds in the Cosmos? The Search for Planets Similar to our Earth and...perhaps Sheltering Life! 14 September 2022

25. Prof. Kazunari Shibata
Kyoto University and Doshisha University, Kyoto, Japan
Threat of the Sun and Superflares 21 September 2022

26. Prof. Siddharth Ramachandran
Electrical Engineering, Physics & Materials Science, Boston University, Boston, MA, USA
Space: the less explored dimension of light 28 September 2022

27. Dr. Christine Amory-Mazaudier
Sorbonne Universit, Ecole polytechnique, Institut Polytechnique de Paris, Universit Paris Saclay, Observatoire de Paris, CNRS, Laboratoire de Physique des Plasmas, Paris, France
SUN EARTH SYSTEM AND SPACE WEATHER: a historical approach-Physics 06 October 2022

28. Prof. Shishir Deshpande
Institute for Plasma Research, Gandhinagar
Nuclear Fusion: Indian Program, ITER Project & Beyond 12 October 2022

29. Shri Sudhanshu Mani
Indian Railway Service of Mechanical Engineers (Retd.), Fellow of Institute of Mechanical Engineers, London
Train 18/Vande Bharat Project, How to exploit the spirit of Atmanirbhar Bharat! 19 October 2022

30. Prof. Anthony J. Leggett (Nobel Laureate)
University of Illinois at Urbana-Champaign
What Can We Do With a Quantum Liquid? 26 October 2022

31. Justice Vikram Nath
Supreme Court of India, New Delhi
Technology & Science in Legal Realm 02 November 2022

32. Dr. Shashank Chaturvedi
Institute for Plasma Research, Gandhinagar
Fusion and Plasma Research in India: Where are we, where are we going? 09 November 2022

33. Prof. Arnab Rai Choudhuri
Department of Physics, Indian Institute of Science, Bangalore
An enigmatic fluid flow inside the Sun: the Meridional Circulation 16 November 2022

34. Dr. Shekhar C. Mande
Savitribai Phule Pune University, Pune and National Centre for Cell Science, Pune
Addressing Indian Societal problems through Science, Technology and Innovation in post-Independent India 22 November 2022

35. Dr. Harsh K. Gupta
NASI Platinum Jubilee Fellow, Geological Society of India, Atomic Energy Regulatory Board, India, National Geophysical Research Institute, Hyderabad
Building Dakshin Gangotri at Antarctica: A Miracle 30 November 2022

36. Prof. K. S. Viswanathan
Krea University, SriCity
Hydrogen bonded interactions: Pawns in the Game of Molecular Chess 08 December 2022

37. Prof. Tarun Souradeep
Raman Research Institute, Bangalore
Propelled by quests: Gravitational wave science 14 December 2022

38. Prof. Jayaram Chengalur
Tata Institute of Fundamental Research, Mumbai
Galaxy evolution: The atomic hydrogen perspective 21 December 2022

39. Prof. Siva Umapathy
Indian Institute of Science, Education and Research, Bhopal
Raman spectroscopy: from Physics to Medicine 28 December 2022

40. Shri A S Kiran Kumar
Physical Research Laboratory, ISRO, Bengaluru, Space Commission, Govt. of India

Vikram Sarabhai and Indian space programme 05 January 2023

41. Dr. K Kasturirangan
Indian Space Research Organization, Government of India
My Professional Forays - People, Challenges & Anecdotes 30 January 2023

42. Prof. Mahesh Anand
The Open University, Milton Keynes, UK
Apollo to Artemis: The Science and Exploration of the Moon 22 February 2023

43. Prof. Asha Kaul
Indian Institute of Management Ahmedabad
DEMYSTIFYING LEADERSHIP 29 March 2023

Conference/Symposium/Workshop organized by PRL

Solar Physics

1. "Origin and evolution of solar eruptive phenomena: observations, modeling and Sun-Earth connection", One day workshop organized jointly with colleagues of IIA, IIT (BHU), Kumaun University, NIT Calicut, 41st Astronomical Society of India (ASI) Meeting (ASI-2023) at IIT Indore, March 1, 2023..

Planetary Sciences

2. "4^{th} Indian Planetary Science Conference (IPSC-2023)", PRL, Ahmedabad, 22-24 March 2023.
3. "IPSA IPSC Workshop on Planetary Exploration: Going Beyond", PRL, Ahmedabad, 20-21 March, 2023.
4. "Meteoroids, Meteors and Meteorites: Messengers from Space Symposium (MetMeSS-2022", PRL, Ahmedabad, 24-25 November 2022.
5. "Venus Science Conference (Venus-SC-2022)", PRL, Ahmedabad, 29-30 September 2022.
6. "National Science Day", PRL, Ahmedabad, 25 February 2023.
7. "High end DST-Karyashala workshop", PRL Ahmedabad, 4-10 July 2022.
8. "Asteroid Day", PRL, Ahmedabad, 10 July 2022.

Geosciences

9. "Second Annual Frontiers and Geosciences Research Conference (FGRC-2023)", Frontiers in Geosciences Research Conference (FGRC) is an annual event of the Geosciences Division of Physical Research Laboratory (PRL) Ahmedabad. FGRC 2023 was the second event organized in-person at PRL during 1^{st}–3^{rd} February, 2023. The major objectives of the conference were to bring the entire Geoscience ccommunity of India on a common platform to disseminate the recent scientific findings, plan the future course of Geoscience research in India, enhance collaborations and knowledge exchange and jointly address societal issues using modern technology. The conference covered almost all fields of geosciences and the researchers presented their works for understanding processes that take place starting from the core of the earth to its atmosphere on all possible spatial and temporal scales. The research activities covered various themes such as causes and consequences of climate change, reconstructing the past climatic conditions, projection of future climate, cycling of carbon and nitrogen in terrestrial and ocean reservoirs, nutrient availability in various oceanic and terrestrial aquatic systems and their role in atmospheric carbon fixation, ocean circulations, dynamics of water above and below the earth's surface, catastrophic events, cryospheric processes and glacier dynamics, rise and fall of ancient civilizations and applications of artificial intelligence and machine learning in various fields of earth sciences.

   FGRC is the only conference in India that covers all the fields of Earth Sciences and has a broad objective of addressing scientific and societal issues from regional to global scale. Almost all the leading geoscientists of India are directly or indirectly involved with FGRC. FGRC-2023 was attended by more than 300 delegates from all corners of the country with more than 80 oral presentations and nearly 150 posters. There were representatives from almost all the states of India with participants from most of the IIT'S, IISERS, universities and research institutes. Students and scientists from nearly 88 universities/institutes participated in the FGRC-2023. Participants include very young students to the superannuated active scientists. FGRC has a strong tie up with many leading national and international scientific instrument suppliers and many of them participated in the FGRC-2023 in addition to partially sponsoring the event.

10. "Workshop on 'Isotopic Applications in Earth Sciences'", A day long workshop on "Isotopic applications in earth Sciences" for M.Sc and early Ph.D students was organized in-person at PRL on 31^{st} January, 2023. The primary aim of the workshop was to create awareness in younger scientific generations about the applications of various stable and radio isotope systematics in different fields of earth sciences and latest developments in the field. About 70 students from various university/institute of India participated in the workshop.12 leading geoscientists of the country delivered lectures in the workshop.

Atomic, Molecular and Optical Physics

11. "Dust-Ice-Gas (DIG) Astrochemistry", The first online conference in astrochemistry (in India/Asia), conducted on 17-18 November 2022. In this online conference, we had 32 speakers from abroad, and it was attended by 120 registered participants.
12. "Astrochemistry and Cratering in the Solar System", Workshop was conducted from 4 to 10 July 2022. This workshop was funded by the DST-SERB.
13. "Asteroid day", Asteroid day was Conducted on 10^{th} July 2022.

14. “7th National Symposium on Shock Waves (NSSW-2023)”, Conducted between 15-17 February 2023.

15. “SCOP-the Students conference in optics and photonics”, PRL Ahmedabad, 28-30 September 2022.

Theoretical Physics

16. “4th PRL CCMP (PRL Conference on Condensed Matter Physics”, PRL, Ahmedabad, February 6-8, 2023.

Invited Talks at Conference / Symposia / Workshops

Astronomy and Astrophysics

Abhijit Chakraborty

1. “PRL2.5-m telescope: first light instruments and projected science cases”, 3rd BINA Workshop, Graphic Era Hill University, Bhimtal, India, 22-24th March, 2023.

Santosh Vadawale

2. “Hard X-ray Polarimeter for Broadband X-ray Polarimetry Mission”, Celebrating 7 Years of AstroSat, ISRO-HQ, Bangalore, 28-29 September, 2022.
3. “GRB Observations with AstroSat-CZTI And Beyond”, MASTER 20th Anniversary Conference: Busrting Universe by Robotic Eyes, Russia, 15-20 August 2022.

Sachindra Naik

4. “Optical and X-ray studies of Be/X-ray binaries during giant X-ray outbursts”, 3rd BINA conference, ARIES, Nainital, India, 21 24 March, 2023.

Aveek Sarkar

5. “Particle acceleration in the heliosphere: X-ray observation of the Sun”, Second workshop of the Aditya-L1 Support Cell, Manipal Academy of Higher Education (MAHE), Manipal, Udupi, Karnataka,, 28-30 Nov., 2022.
6. “Numerical tools to understand the generation of Solar Energetic Particles”, Astronomical Society of India, 2023, Department of Astronomy, Astrophysics and Space Engineering, Indian Institute of Technology, Indore, 1-5 March, 2023.
7. “Anisotropy in solar wind”, Science from in-situ Measurements of Aditya L1 (SIMA-01), SPL, VSSC, Thiruvananthapuram, Kerala, 11-13 April, 2023.

Mudit K Srivastava

8. “Spectroscopy Evolution of Nova V2891 Cygni: Evidence for Shock-Induced Processes”, 7th National Symposium on Shock Waves, Physical Research Laboratory, Ahmedabad, 15-17 February, 2023.

Manash Samal

9. “The Early Life of Massive Stars: Formation and Feedback Effects”, 104-cm Sampurnanand Telescope Golden Jubilee Workshop, ARIES, Nainital, India, 17-19 th October, 2022.

Veeresh Singh

10. “Radio galaxies in the remnant phase”, URSI-regional conference on Radio Science, IIT Indore, 01-04 December 2022.

Mithun N. P. S.

11. “X-ray Polarimetry by Scattering and GEANT4”, 1st National Workshop on GEANT4 and its application to High-Energy Physics and Astrophysics, IUCAA, Pune, 05 - 09 Dec, 2022.

Solar Physics

Rohan Louis

12. “Homologous Flaring Activity over a Sunspot Light Bridge in an Emerging Active Region”, Workshop no. 3 of 41st Meeting of ASI 2023 titled ”ORIGIN AND EVOLUTION OF SOLAR ERUPTIVE PHENOMENA: OBSERVATIONS, MODELING AND SUN-EARTH CONNECTION”, IIT Indore, 1 March 2023.

Girjesh Gupta

13. “Tracing the source region of waves in coronal fan loops anchored in the sunspot umbra”, 3rd BINA-workshop Organised by ARIES, Nainital, Graphic Era Hill University, Bhimtal, 22-24 March 2023.

Binal D. Patel

14. “Near-Sun and interplanetary characteristics of coronal mass ejections associated with DH-type II radio bursts”, Workshop on the topic Origin and Evolution of Solar Eruptive Phenomena: Observations, Modeling and Sun-Earth Connection, IIT Indore, 1 March 2023.

Bhuwan Joshi

15. "Solar magnetic ux ropes: Build-up, early evolution and eruption", VELC/ Aditya-L1 Science Workshop, Kodaikanal Solar Observatory, Indian Institute of Astrophysics (IIA), 8-10 June 2022.

16. "Physics of Solar Flare", Regional Workshop on Solar Science with Aditya-L1 organized by Science Programme Office, ISRO HQ, St. Joseph University (SJU), Bangalore, 2-6 January 2023.

17. "The Physics of Large-scale Eruptive Processes in the Solar Atmosphere", 3rd Aditya-L1 Support Cell (AL1SC) Workshop, IIT (BHU), Varanasi, 25-27 February 2023.

18. "Onset and evolution of solar flares: Application of 2D and 3D models of magnetic reconnection", 3rd Belgo-Indian Network for Astronomy and Astrophysics (BINA) Workshop, Graphic Era Hill University, Bhimtal, 22-24 March 2022.

Nandita Srivastava

19. "National ISWI Activity", ISWI Steering Committee Annual Meeting, Vienna, 10 February 2023.

20. "Forecasting the space weather", Workshop on science and technology, Pt. Ravishankar Shukla University, Raipur, 15-18 October 2022.

21. "Monitoring the Solar Activity from Ground-based instruments", 'Akash for life' Conference organized by ISRO, IIRS, Dehradun, 5-6 November 2022.

Space and Atmospheric Sciences

Duggirala Pallamraju

22. "Space Weather Science and its effect on Space Applications", Short Course on Space Weather" conducted by UN-CSSTEAP, hosted by PRL, 20-30 Dec, 2022.

23. "New insights on the precursors to the onset of equatorial plasma irregularity generation", URSI-RCRS, IIT-Indore, 1-4 Dec, 2022.

24. "Recent Results Obtained on the Equatorial Dynamical Processes Using OI 630.0 nm Dayglow Emission Variability and Key Insights Obtained on the Production Mechanisms", 19^{th} AOGS meeting, Singapore, 1-5 Aug, 2022.

25. "Variations in OI 630.0 nm dayglow and nightglow emissions over low- / equatorial latitudes and their dependence on neutral winds and equatorial electric fields", 44^{th} COSPAR Scientific Assembly, Athens, Greece, 16-24 Jul, 2022.

26. "Importance of lower & middle atmospheric processes on MLT dynamics, Brainstorming meeting on middle atmosphere research using Lidars", held in hybrid mode, at NARL, 24 May, 2022.

27. "Disturbed and quiet time Ionosphere-thermosphere System at High Altitudes (DISHA) H & L: ISRO's proposed twin Aeronomy satellite mission", National Meet on Aeronomy Research on Science of near Earth Space and its Application, ., 10 May, 2022.

S. Ramachandran

28. "Recent Aerosol Trends over Asia: Observations and Simulations", Workshop on atmospheric satellites for Asian monsoon cloud-precipitation science and applications (WASAMA 2022), Institute for Advanced Research in Science (IARSc), Bengaluru, 21-24 Jun, 2022.

29. "Light-absorbing aerosols and climate in South Asia", ANPA Conference 2022, Old Dominion University, Norfolk, Virginia, USA, 15-17 Jul, 2022.

30. "Climate Change vs. Ozone", 2^{nd} Skill Development Programme on "Human Impacts on Environment", Madurai Kamaraj University, Madurai, 22-31 Aug, 2022.

31. "Ozone and Climate Change", Climate Science Awareness Programme for Teachers, Gujarat Science City, Ahmedabad, 25-26 Aug, 2022.

32. "Ozone and Climate Change", International Ozone Day, Pushpa Gujral Science City, Kapurthala, 16 Sept, 2022.

33. "Recent Aerosol Trends over Asia: Air Pollution Reductions and Climate Benefits", SDG 2030 International Workshop, University of Gothenburg, Sweden, UC Berkeley, and IIT Delhi, Delhi, 10-11 Oct, 2022.

34. "Public Lecture on "Air Pollution and Climate Change: Challenges"", PRL Conference on Condensed Matter Physics (CCMP) 2023, Physical Research Laboratory, Ahmedabad, 6-8 Feb, 2023.

35. "Keynote Address on "Atmospheric Aerosols and Climate Change: Challenges"", National Workshop on Boundary Layer Exchange Processes and Climate Change (NoBLExClim 2023), SRM Institute of Science and Technology (SRMIST), Chennai, 23-24 Mar, 2023.

D. Chakrabarty

36. "Aditya Solar Wind Particle Experiment", at the Science from In-situ Measurements from Aditya-L1 (SIMA-01) meeting, organized by SPL, VSSC, 11-13 Apr, 2023.

37. "The story of Helium in solar wind", in the USO Solar Physics Workshop (USPW-2023) entitled "Multi-scale Phenomena on the Sun: Present Capabilities and Future Challenges", USO, Udaipur, 03-05 Apr, 2023.

38. "How Aditya-L1 mission can help in Space weather investigations", in the Conference On Frontiers in Space and Atmospheric Sciences (COFSAS-2023), ., 15 Mar, 2023.

39. "Planetary Space weather - a primer", in the two-day workshop on Planetary Sciences and Exploration, organized by the Indian Planetary Sciences Association (IPSA) at, PRL, Ahmedabad, 20-21 Mar, 2023.

40. "Probing the Heliosphere and Space Weather through In Situ Measurement of Particles and Radiations", 3^{rd} Aditya-L1 Workshop, IIT (BHU), 25-27 Feb, 2023.

41. "Space weather and planetary impact", Regional Workshop on Solar Science and Aditya-L1, organized by ISRO-HQ in association with St. Joseph University (SJU), St. Joseph University, Bengaluru, 02-06 Jan, 2023.

42. "Aditya-L1 mission of India and investigation of solar wind plasma", 37^{th} National symposium on Plasma Science and Technology (PLASMA-2022), IIT-Jodhpur, 12-14 Dec, 2022.

43. "Remote sensing of ionospheric space weather through radio waves: New insights", URSI - RCRS 2022, IIT-Indore, 1 - 4 Dec, 2022.

44. "Solar wind interaction with Venus: An oxygen airglow perspective", Venus Science Conference 2022 (Venus-SC-2022), PRL, Ahmedabad, 29 - 30 Sept, 2022.

45. "Evidences for the role of IMF By in the equatorial ionospheric electrodynamics", in session C0.3 in COSPAR 2022, Athens, Greece, 16 - 24 Jul, 2022.

46. "Aditya-L1 mission of India and potential of in-situ measurements", in session C3.2 in COSPAR 2022, Athens, Greece, 16 - 24 Jul, 2022.

Lokesh Kumar Sahu

47. "Volatile Organic Compounds - Study of primary emissions and photochemical processes", Aakash Workshop, New Delhi, 28 - 29 Mar, 2023.

48. "Role of Institute of Repute (IoR) for implementation of NCAP", Brainstorming Workshop on Air Quality Management and Emission Reduction for Cities in Gujarat, Gujarat Pollution Control Board (GPCB), Gandhinagar, 21 Jul, 2022.

49. "Importance of short-live trace gases and their role in atmospheric chemistry over South Asia", First Interaction Meeting on Research Trends in Atmospheric Science: Science Programme Office, ISRO Headquarters, Bangalore, 22 Feb, 2023.

50. "Importance of biogenic VOC emissions and their role in atmospheric chemistry over South Asia", integrated Land Ecosystem-Atmosphere Processes Study (iLEAPS) Conference, ., 09 May, 2022.

Som Kumar Sharma

51. "Investigation of Atmospheric Clouds and Boundary Layer: Importance in Modulating Air quality", The Integrated Land Ecosystem-Atmosphere Processes Study (iLEAPS), ., 22 Apr, 2022.

52. "LIght Detection And Ranging (LIDAR): A Versatile Tool to Explore the Earth's Lower and Middle Atmosphere", International Workshop on Technical and Scientific aspects of Lidar Remote sensing of the Atmosphere (ITSLRA-2022), Sathyabama Institute of Science and Technology, Chennai, 13-14 Jul, 2022.

53. "Inaugural Speech as Chief Guest on topic "Earth's Lower and Middle Atmospheric Studies: Role of Clouds"", at Valedictory function of DST-INSPIRE, Graphic Era University, Dehradun, 29 Nov, 2022.

54. "Investigation of the Cloud Characteristics and their Impact on Atmospheric Processes", URSI-RCRS-2022, Indian Institute of Technology (IIT), Indore, 1- 4 Dec, 2022.

55. "Lower and Middle Atmospheric Processes, Clouds, Boundary Layer and Long-term changes in the Atmosphere", at discussion on the "Recent Research Trends in Atmospheric Science Focusing on the Tropospheric Layer over India", SPO, ISRO Headquarters, Bangalore, 22 Feb, 2023.

56. "Role of Ground and Satellite Based Remote Sensing in improving Atmospheric models", Satellite Meteorology and its Application in Numerical Weather Prediction, NESAC, Shillong, 15 Mar, 2023.

57. "Atmospheric Investigations of Clouds and Boundary Layer Characteristics using LIDAR", Department of Physics, University of Dibrugarh, Dibrugarh, 17 Mar, 2023.

58. "Comprehensive Investigations of the Atmospheric Boundary Layer: Scientific and Societal Perspectives", National Workshop on Boundary Layer Exchange Processes and Climate Change (NoBLExClim 2023), SRM Institute of Science and Technology (SRMIST), Chennai, 23-24 Mar, 2023.

Harish Gadhavi

59. "LIDAR algorithms for aerosol extinction retrieval", International Workshop on Technical and Scientific aspects of Lidar Remote Sensing of the Atmosphere, Sathyabama Institute of Science and Technology, Chennai., 13-15 Jul, 2022.

K. Venkatesh

60. "Parametric dependence of topside ionospheric structure in the NeQuick2 model over the equatorial and low latitudes", 44^{th} COSPAR Scientific Assembly, Athens, 16-24 Jul, 2022.

61. "Longitudinal and hemispheric variabilities of the low latitude ionospheric dynamics and space weather effects", Conference on Frontiers in Space and Atmospheric Sciences (COFSAS-2023), ., 15-16 Mar, 2023.

Narendra Ojha

62. "Modeling of atmospheric trace gases and aerosols over the South Asian region", Conference on Frontiers in Space and Atmospheric Sciences (COFSAS)-2023, ., 15-16 Mar, 2023.

Yogesh

63. "Enrichment of Helium abundance in Interplanetary Coronal Mass Ejections: Insights", in the 41^{st} Annual Meeting of the Astronomical Society of India (ASI), IIT Indore, 1-5 Mar, 2023.

64. "Investigations on the alpha-proton ratio in the solar wind using ASPEX measurements", in Aditya-L1 Science Support Cell (AL1SSC) workshop, ARIES, Nainital, 27 Jun - 6 Jul, 2022.

Mansi Gupta

65. "Air-sea exchange of Dimethylsulfide (DMS) and its potential controls over the northern Indian Ocean", International Indian Ocean Science Conference (IIOSC) - 2023, Perth, Australia, 6-10 Feb, 2023.

Bijoy Dalal

66. "Investigations on energetic particles in the solar wind using ASPEX measurements", in the first Aditya-L1 Science Support Cell (AL1SSC) workshop, ARIES, Nainital, 27 Jun - 6 Jul, 2022.

Planetary Sciences

Anil Bhardwaj

67. "Indian Planetary Missions and Science", 44^{th} COSPAR Scientific Assembly, Athens, Greece, 16-24 July, 2022.

68. "Exploration of Venus", Second Venus Science Conference, PRL, Ahmedabad, 29 Sept., 2022.

69. "Indian Planetary Missions", URSI-RCRS-2022, IIT Indore, 02 Dec., 2022.

70. "Indian Planetary and Space Missions", 108^{th} Indian Science Congress, R.T.M. Nagpur University, Nagpur, 4 Jan., 2023.

Jayesh P. Pabari

71. "Interplanetary Dust Science", Short Course on Space Weather, PRL, Ahmedabad, 20-30 December 2022.

72. "Heliocentric dependence of IDP density in light of SO Observations", Venus Science Conference (Venus-SC-2022), PRL, Ahmedabad, 29-30 September 2022.

Dwijesh Ray

73. "Terrestrial Impact Craters: Identification, Challenges and future scope", Workshop on Astrochemistry and Cratering in Solar System, PRL, Ahmedabad, 4-10 July 2022.

K. Durga Prasad

74. "An improved approach for deriving plasma characteristics from langmuir probe observations onboard a future Mars mission", 44^{th} COSPAR Scientific Assembly, Athens, Greece, 16-24 July 2022.

Kinsuk Acharyya

75. "Exploring extra-terrestrial life Is it vital?", 23^{rd} Odisha Bigyan O Paribesh Congress (OBPC), Sambalpur, November 26-27, 2022.

Neeraj Srivastava

76. "Recent volcanism on the Moon: Current understanding and implications", Forming & Exploring Habitable Worlds Conference, Edinburgh, Scotland, UK, 7th 13th Nov. 2022.

77. "Indian Planetary Missions: Key findings & implications", Workshop on Space Sciences and Exploration, Panjab University, Chandigarh, 27-28 August 2022.

78. "Lunar geology and it evolution", Astrochemistry and Cratering in Solar System, PRL, Ahmedabad, 4-10 July 2022.

Sanjay Kumar Mishra

79. "A charge dissipation mechanism within permanently shadowed craters", 9^{th} International Conference on the Physics of Dusty Plasmas (ICPDP) 2022, Moscow, Russia, May 23-27, 2022.

80. "Complex electrostatic structures within craters over sunlit Moon", 9^{th} International Conference on the Physics of Dusty Plasmas (ICPDP) 2022, Moscow, Russia, May 23-27, 2022.

Shanmugam M

81. "PRL Space Payloads", Astrochemistry and Cratering in Solar System, DST Karyashala, PRL, Ahmedabad, 4-10 July 2022.

82. "In-situ Observations of Particles: ASPEX payload on-board Aditya-L1", Regional workshop on Solar Science and Aditya-L1, St. Joseph University, Bangalore, 02-06, Jannuary, 2023.

S.A. Haider

83. "The magnetically controlled ionopause boundary observed by LPW onboard MAVEN within magnetic pile-up region of Mars", 44^{th} COSPAR Scientific Assembly, Athens, Greece, 16-24 July, 2022.

84. "Atmospheric escape from Mars and Venus", Venus Science Conference (Venus-SC-2022), PRL, Ahmedabad, 29-30 September 2022.

Geosciences

S. Kumar

85. "Too much or too little the story of nitrogen in our environment", Platinum Jubilee Celebrations Seminar Series, Patna University, Patna, April, 2022.

N. Rastogi

86. "Oxidative Potential of Atmospheric Aerosols over India", first International Symposium on "SecoNdary Aerosol FormatioN and GrOwth-2023 (NANO-2023)" organized by Finnish Meteorological Institute and Hyderabad Central University, Hyderabad, March 13^{th} – 14^{th}, 2023.

87. "Carbonaceous Aerosols: Sources, Composition, and Importance", Winter School on "Hands on Training on Instrumentation and Analytical Techniques for Atmospheric Aerosol Measurements and Source Apportionment Studies" organized by Central University of Jammu, Jammu, J&K, Feb 20^{th} – 25^{th}, 2023.

88. "Analytical Techniques to Assess Carbonaceous Aerosols: Pros and Cons of Offline and Online Measurements", Winter School on 'Hands on Training on Instrumentation and Analytical Techniques for Atmospheric Aerosol Measurements and Source Apportionment Studies' organized by Central University of Jammu, Jammu, J&K, Feb 20^{th} – 25^{th}, 2023.

89. "Aerosol Oxidative Potential: Relating Air Pollution and Human Health", National Workshop on "Air Pollution and Health Impacts" organized by Central University of Jammu, Jammu, J&K, June 1^{st}, 2022.

90. "Ambient Air Measurements to Study Air Pollution and Climate Change", in "India Clean Air Summit (ICAS) 2022" organized by the Centre for Air Pollution Studies (CAPS) at the Center for Study of Science, Technology and Policy (CSTEP), and the Air Sensors International Conference (ASIC) India Chapter, Bangalore, Aug 23^{rd} – 26^{th}, 2022.

A. Singh

91. "Integrated Studies of High Sensitivity Systems: Indian Ocean", SOLAS SSC meeting, Cape Town, South Africa, Oct 1^{st}, 2022.

92. "Ocean and its role in climate", on World Environmental Day, Science City, Ahmedabad, June 5^{th}, 2022.

93. "Do we have a solution of climate change in the ocean?", on World Earth Day, NIO, Goa, April 21^{st}, 2022.

M. G. Yadava

94. "Indian Summer Monsoon variability during mid-Holocene: Inferences from stalagmite δ^{18}O record", Oral presentation given in Session 2 at Second Frontiers in Geosciences Research Conference (FGRC), PRL, Ahmedabad, Feb 1^{st} – 3^{st}, 2023.

Atomic, Molecular and Optical Physics

R. P. Singh

95. "Experiments to Improve Security and Key Rate in Free Space Quantum Communication", International Conference on Quantum Information and Quantum Technologies (QIQT-2022), IISER Kolkata, 1 June - 4 July 2022.

96. "Quantum Communication: Case for Quantum Key Distribution", National Symposium in Quantum Technologies (NSQT-2022), IIT Hyderabad, 11 - 13 April 2022.

97. "Free Space Quantum Communication: Road to Satellite Quantum Communication", QuEST Theme-1 Workshop, Punjabi University, Patiala, 1-2 April 2022.

98. "Development of Satellite-based Quantum Key Distribution", Workshop on Quantum Technologies, Scientific Analysis Group, DRDO, New Delhi, 5-6 May 2022.

99. "Free Space Quantum Communication", DAE-BRNS National Laser Symposium (NLS-31), IIT Kharagpur, 3-6 December 2022.

100. "Space quantum technologies: A step towards satellite-based quantum key distribution", XLV Symposium of the Optical Society of India, Conference on Optics, Photonics and Quantum Optics (COPaQ-2022), IIT Roorkee, 10-13 November 2022.

101. "Discrete and continuous variable entanglement: Some applications", Indo-Russia Seminar on Quantum Technologies, IISER Pune, 20-21 August 2022.

102. "Quantum signature of photons with orbital angular momentum", Discussion Meeting on Structured Light and Spin Orbit Photonics, TIFR-ICTS, Bengaluru, 29 November 02 December 2022.

103. "Quantum Technology: Present and Future", International Workshop on Quantum Communication and Quantum Computing, IEEE ANTS 2022, IIT Gandhinagar, 19^{th} December 2022.

104. "Quantum Technologies & Photonics: Application Oriented Research", 108^{th} Indian Science Congress in Front Line Areas of Research in Strategic Sector, Session, RTM Nagpur University, Nagpur, 3-7 January 2023.

105. "Coincidence Detection QKD Protocol", Workshop 2 of International Network in Space Quantum Technologies (INSQT), RAL Space, Harwell, UK, 13-15 February 2023.

106. "QKD in Satellite Communication", First International Quantum Communication Conclave organized by TEC, C-DOT, TSDSI in technical collaboration with IEEE Communications Society-Delhi Chapter, Vigyan Bhawan, New Delhi, 27-28 March 2023.

Shashi Prabhakar

107. "Spatial modes of light in turbulence and their quantum effects", Structured Light and Spin-Orbit Photonics, International Centre for Theoretical Sciences, International Centre for Theoretical Sciences, 2^{nd} December 2022.

108. "Quantum effects under turbulence", Summer School on Quantum Information and Quantum Technology 2022 (QIQT-2022), IISER Kolkata, 3 June 2022.

109. "Quantum research @ Physical Research Laboratory", Seminar on Space Quantum Frontiers, National Technology Day 2022, Space Application Centre (SAC), 19 May 2022.

Prashant Kumar

110. "Solar Wind Ion Spectrometer (SWIS): Instrument capability, preliminary test and ground calibration results", 40^{th} meeting of the Astronomical Society of India (ASI-2022), IIT Roorkee, 25 - 29 March 2022.

Bhalamurugam Sivaraman

111. "Graphene and quantum dots important constituent of PAH containing ISM dust", Life cycles of Cosmic PAHs conference, Aarhus University, Denmark, 5-9 September 2022.

112. "Laboratory Astrochemistry", Spectroscopy and Dynamics of Molecules conference (SDMC 2022), Manglore, Karnataka, 10-13 November 2022.

Rajesh Kumar Kushawaha

113. "Photoionization of Polyatomic Molecules: Molecular Structure, Ultrafast Dynamics and Molecular Movie", 14^{th} Asian International Seminar on Atomic and Molecular Physics, University of Melbourne, Australia, 13-17 February 2023.

B. K. Sahoo

114. "A Complete Analysis of Closed-shell Atomic EDMs: case study of Xe atom", International Conference on Searches for Electric Dipole Moments: from theory to Experiment, Kobayashi- Maskawa Institute for the Origin of Particles and the Universe (KMI), Nagoya University, 2 - 4 March, 2023.

115. "Probing Nuclear Structures using High Precision Atomic Studies", 23^{rd} National Conference on Atomic and Molecu- lar Physics (NCAMP 2023), IIST Trivendrum, 20 - 23 February, 2023.

116. "Highly Charged Ions as Frontier Clock Candidates for Testing alpha Variation", The Constancy of the Fundamental Constants, IUCAA, Pune, 1 - 2 December 2022.

117. "Relativistic Coupled-Cluster Theory of Parity Violation in 133Cs", the international workshop on Atomic Parity Violation (APV 2022), FPUA, Japan, 28 - 30 November, 2022.

118. "Atomic Parity Nonconservation", International workshop on Precision Tests with Neutral Current Interactions with Nuclei, Mainz University, Germany, 23 - 27 May, 2022.

Goutam Kumar Samanta

119. "Nonlinear interaction and the generation of structured beams", Structured Light and Spin-Orbit Photonics, ICTS Bangalore, 29 Nov. - 02 Dec. 2022.

120. "Bright quantum source for quantum sensing", Conference on Optics, Photonics, and Quantum optics (COPaQ-2022), IIT Roorkee, India, 10 - 13 November 2022.

121. "Entangled photon source for satellite-based quantum communication", Summer School on Quantum Information and Quantum Technology - 2022 (QIQT-2022), IISER Kolkata, 1 - 4 June 2022.

122. "Are we ready with the indigenous entangled photon source for Indian space-based quantum technologies?", Space Quantum Frontiers, Space Applications Centre, Ahmedabad, 19 May 2022.

123. "Quantum key distribution: Principle to practice", Guest Lecture, Ahmedabad University, Ahmedabad, 23^{rd} March 2022.

Dipen Sahu

124. "Density profile of centrally dense prestellar cores", Seminar at National Astronomical Observatory of Japan (NAOJ), National Astronomical Observatory of Japan (NAOJ), Mitaka, Tokyo, Japan, April 20, 2023.

Naveen Chauhan

125. "Understanding the Dose Rate for Luminescence Dating", 4^{th} Workshop on Luminescence Dating and Applications, IISER Kolkata, 1-3 February 2023.

126. "New Protocols for Feldspars", 4^{th} Workshop on Luminescence Dating and Applications, IISER Kolkata, 1-3 February 2023.

Theoretical Physics

Srubabati Goswami

127. “Analytic treatment of neutrino decay and oscillation in matter”, Neutrino Oscillation Workshop, Brindisi, Italy,, 4 -11 September, 2023.

128. “Future Goals in Neutrino Physics”, Horizons in Particle Accelerators and Laboratory-Based Quantum Sensors, ICTS, Bengaluru, 14 - 17 November, 2022.

129. “Neutrino Physics: Current Status and Future Trends”, AAPCOS 2023, Saha Institute of Nuclear Physics, Kolkata, 23 - 27 January, 2023.

130. “BSM phenomenology and neutrinos”, International Meeting on High Energy Physics 2023, Institute of Physics, Bhubaneswar, 16 - 22 February, 2023.

131. “The Neutrino Landscape”, Workshop on Particle physics, Astrophysics and Cosmology, Shiv Nader University, Delhi, 21 - 22 March, 2023.

Namit Mahajan

132. “ALP Couplings to Heavy Hadrons”, Heavy Hadrons in Heavy Ion and Particle Collisions, IIT Gandhinagar, 24 - 25 March, 2023.

Partha Konar

133. “Deep Learning in Particle Physics”, Frontiers in Particle Physics 2023, Indian Institute of Science, Bangalore, 10 - 12 March, 2023.

134. “LHC search and QCD - In an era of Deep Learning”, International Meeting on High Energy Physics (IMHEP II), Institute of Physics, Bhubaneswar, 16 - 22 Feb, 2023.

135. “Low-level data in LHC search and QCD - Advent of Deep Learning”, Meeting on high energy physics 2023, Indian Institutes of Science Education and Research, Kolkata, 16 - 21 November, 2022.

Ketan M. Patel

136. “Predicting Leptonic Charge-Parity Violation”, Royal Society Yusuf Hamied Workshop for India and the UK, online, 23 February, 2023.

137. “Fermion Mass Hierarchies through Quantum Corrections”, Frontiers in Particle Physics 2023, Indian Institute of Science, Bangalore, 10 - 12 March, 2023.

Paramita Dutta

138. “Generation and detection of odd-frequency Cooper pairs in topological Josephson junctions”, Young Investigators Meet on Quantum Condensed Matter Theory (YIMQCMT), NISER, Bhubaneswar, 29 October - 01 November, 2022.

Satyajit Seth

139. “Compact One-Loop Amplitudes: H+2-jet production”, International Meeting on High Energy Physics 2023, Institute of Physics, Bhubaneswar, 16 - 22 February, 2023.

Computer Networking and Information Technology (CNIT) Division

Jigar Raval

140. “Cyber Safe Behavior - #See Yourself in Cyber”, National Science Day 2023 at PRL, Physical Research Laboratory, Ahmedabad, February 24, 2023.

141. “Cyber Security A Comprehensive Approach”, International Corporate-Academia Summit on AI and Cyber Security Interventions, Karnavati University, Ahmedabad, January 20, 2023.

142. “Think Before You Click”, online expert talk on Think Before You Click, Indian Institute of Remote Sensing (IIRS), Dehradun, October 17, 2022.

143. “Cyber Safe Behavior”, Hindi Maah Celebration, PRL, Ahmedabad, October 08, 2022.

144. “See Yourself in Cyber Safeguard from Cyber Threats”, online expert talk on See Yourself in Cyber Safeguard from Cyber Threats, Wadia Institute of Himalayan Geology (WIHG), Dehradun, October 06, 2022.

145. “Computational Services at PRL & Cyber Security Awareness”, Digital India Week celebrations, PRL,Ahmedabad, July 07, 2022.

146. “Security Ourselves from Phishing Threats”, expert talk on Security Ourselves from Phishing Threats, Ahmedabad Management Association (AMA), May 28, 2022.

147. “Parallel Processing Using Our Super Computer”, expert talk on Parallel Processing Using Our Super Computer, Silver Oak University, Ahmedabad, April 23, 2022.

Lectures at Universities / Institutions

Astronomy and Astrophysics

Abhijit Chakraborty

1. “Exoplanet Instrumentation and Sciences in India”, Invited talk delivered at the Chandigarh University, Gharuan, Mohali, Punjab India, November 2022
2. “Radial Velocity Instrumentation and limitations on Exoplanet detection”, Invited talk organised by IISER Pune, March 2023

Shashikiran Ganesh

3. “Evolution of telescopes and our understanding of the Milky Way”, Invited lecture in the Workshop on Space Sciences and Technology, Department of Physics, Panjab University, Chandigarh, August 27, 2022
4. “Minor Bodies of the Solar System”, Invited talk at a webinar organised by Sri Lanka Association for the Advancement of Science, Colombo, Sri Lanka,, February 11, 2023

Vishal Joshi

5. “Secrets of the universe”, Invited lecture at G H Patel College of Engineering, Vallabh-VidyaNagar, Gujarat, April 11, 2022
6. “A virtual visit to an astronomical observatory”, Pandit Dindayal Energy University, Gandhinagar, Gujarat, February 28, 2023

Solar Physics

Rohan Louis

7. “Sunspot light bridges: magnetic configuration and activity”, International School of Space Science [The different spatio-temporal scales of the solar magnetism] organized by Consorzio Interuniversitario per la Fisica Spaziale, L’Aquila, Italy, April 12, 2022

Nandita Srivastva

8. “CMEs and Space Weather”, Short Course on Space Weather organized by UN-CSSTEAP, December 20-21, 2022

Brajesh Kumar

9. “Solar Internal Structure and Dynamics”, Short Course on Space Weather organized by UN-CSSTEAP, December 20-21, 2022

Girjesh Gupta

10. “Introduction to coronal heating”, Short Course on Space Weather organized by UN-CSSTEAP, December 20-21, 2022

Binal Patel

11. “Characteristics of DH type II bursts associated CMEs in the near-Sun region and beyond”, Space Science Division, Korea Astronomy and Space Science Institute,Deajon, Republic of Korea, August 11, 2022

Bhuwan Joshi

12. “The Sun and Space”, Virtual Workshop for Science and Maths Teachers of Govt. Schools of Udaipur, District Institute of Education and Training (DIET), Udaipur, July 1, 2022
13. “Our Sun and space weather”, Workshop for secondary and higher secondary school teachers organized by School Education Department, Govt. of Rajasthan, Udaipur, October 14, 2022
14. “Indian space-based solar observing programs: Observations from XSM/Chandrayaan-2 and future Aditya-L1 space mission”, Korea Astronomy and Space Science Institute (KASI), Daejeon, South Korea, August 12, 2022
15. “Activation of solar magnetic flux ropes and onset of coronal mass ejections”, Korea Astronomy and Space Science Institute (KASI), Daejeon, South Korea, August 19, 2022
16. “Aspects of 3D magnetic reconnection in solar flares”, Department of Astronomy and Space Science, Kyung Hee University, August 25, 2022
17. “The Dynamic Sun and Space Weather”, General Physics Lecture Series, Golden Jubilee Celebrations of HNB Garhwal University (Online), February 21, 2023
18. “Sun and Space Weather”, State level Workshop for Science and Maths lecturers, Rajasthan State Council of Educational Research & Training, Udaipur, March 18, 2023

19. "Active and explosive Sun: space and ground-based observations", Short Course on Space Weather organized by UN-CSSTEAP, December 20-21, 2022

Space and Atmospheric Sciences

Duggirala Pallamraju

20. "Space Weather: A multi-disciplinary frontier area of research", MIT World Peace University, Pune, February 14, 2023
21. "Space Weather Research at PRL: Recent results and Future opportunities", Savitribai Pune University, Pune, February 14, 2023
22. "What is Space Weather and Why should we care about it?", IMRESS Program, Indian Institute of Geomagnetism, Navi Mumbai, February 15, 2023

Dibyendu Chakrabarty

23. "Two invited lectures at Space Applications Center, ISRO, on "Space weather"", in the fourth PG Course of CSSTEAP in Global Navigation Satellite Systems (GNSS-4), March, 2023
24. "Three invited lectures on various aspects of Space weather", to the participants of the Short school on Space Weather organized by CSSTEAP and conducted by PRL, December 20-30, 2022

Harish Gadhavi

25. "Role of Aerosol and Trace-gases in Earth's Climate", Refresher Course in Physics, UGC Human Resource Development Centre, Gujarat University, Ahmedabad, June 2022

Ravindra Pratap Singh

26. "MLT Temperatures and meridional circulation during SSW Events", Institute for Space-Earth Environmental Research (ISEE), Nagoya University, Japan, October 27, 2022
27. "12^{th} Post Graduate Course in Space and Atmospheric Sciences (SAS) of CSSTEAP", affilliated to the united nations, conducted 2-practicals on "identification of Fraunhofer lines using a grating based spectrograph" and "derivation of rotational temperatures from OH nightglow measurements", .

Narendra Ojha

28. "Modelling of Atmospheric Trace Gases and Aerosols over the Indian Subcontinent", 2021 ICTP Prize ceremony, The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy, July 27, 2022

Som Kumar Sharma

29. "Earth's Atmosphere: Its Uniqueness, Importance, and Investigations", at Punjab University, Chandigarh, August 27, 2022

Planetary Sciences

Megha Bhatt

30. "Lunar elemental abundance estimation: A novel method based on Chandrayaan-2 CLASS and Chandrayaan-1 Moon Mineralogy Mapper datasets", School of Physical Sciences, Open University, Milton Keynes, UK, 15 November, 2022

Neeraj Srivastava

31. "Lunar Volcanism: The Tell-tale from a few Pre-Nectarian Basins", The Open University, UK, 15th Nov. 2022
32. "Indian Planetary Exploration: Milestones and Road ahead", Geological Survey of India (Karnataka & Goa), Azadi Ka Amrit Mahotsav (AKAM) celebrations, 5th Sept. 2022

K. Durga Prasad

33. "Exploration of the Moon and beyond", Dept. of Physics, Andhra University, Visakhapatnam, 18th Nov. 2022
34. "Nuances of Planetary Science and Exploration", Dept. of Meteorology & Oceanography, Andhra University, Visakhapatnam, 18th Aug. 2022

Geosciences

R. Bhushan

35. "Principles and Working of Elemental Analyser: Application in Earth Sciences", Department of Earth Sciences, KSKV Kutchch University, Bhuj as part of the DST-FIST Training Programme, August 01, 2022
36. "Paleoclimatic Studies and Their Proxies", Department of Earth Sciences, KSKV Kutchch University, Bhuj as part of the DST-FIST Training Programme, August 01, 2022

Atomic, Molecular and Optical Physics

R. P. Singh

37. "Introduction to quantum communication", Seminar at Deen Dayal Upadhyay College, Delhi University., March 29, 2023
38. "Free space quantum communication: Road to satellite-based quantum communication", Colloquium at NPL, New Delhi., August 26, 2022
39. "Space quantum technologies: A step towards satellite-based quantum key distribution", Talk at the Inaugural function of the Centre for Quantum Technologies (CQT) at IIT Delhi, November 19, 2023
40. "Experiments in free space quantum key distribution", LMI: Seminar at The Centre for Light Matter Interaction, Tel Aviv University, Israel., March 8, 2023

Bijaya Sahoo

41. "Recent theoretical advances in atomic parity violation and isotope studies", A seminar at the Department of Physics, Hongo Campus, Tokyo University, Japan., August 28, 2022.

Bhalamurugan Sivaraman

42. "Laboratory astrochemistry", Inorganic and Physical Chemistry Department, IISc Bangalore., March 8, 2023
43. "Biography of molecules beyond Earth", VIT University (Vellore), March 13, 2023
44. "Mote of dust suspended in a shockwave", VIT University (Vellore), March 15, 2023

Dipen Sahu

45. "From collapsing molecular clouds to planets - the astrochemical link", Seminar at The Department of Applied Physics, The Maharaja Sayajirao University of Baroda, February 7, 2023

Theoretical Physics

Namit Mahajan

46. "Effective Theories and Renormalization", A lecture given at Department of Physics, S.P. University, Vallabh Vidyanagar., 13 Mar, 2023

Partha Konar

47. "LHC search to QCD - In an era of Deep Learning", A colloquium given at School of Physical Science, Indian Institute of Technology (IIT), Indore., 27 Jan, 2023

Ketan M. Patel

48. "Lepton Flavour Violation", A tutorial given at the school on Future Flavours, International Centre for Theoretical Sciences, Bengaluru., 3 May, 2022

Paramita Dutta

49. "Bogoliubov Fermi surface and exotic Cooper pairs in j=3/2 superconductors", A lecture given at S. N. Bose National Centre for Basic Sciences (SNBNCBS), Kolkata, India, 24 Aug, 2022

Satyajit Seth

50. "QCD@LHC", Friday Lecture Series at NIT, Silchar, Assam, 18 Nov, 2022

V. K. B. Kota

51. "Moments and SU(N) algebra for Embedded Unitary Ensemble", Bielefeld (Germany) - Melbourne (Australia) Random Matrices Seminar Online, 7 Dec, 2022

Science Outreach Talks by PRL Scientists

Anil Bhardwaj

1. “Indian Planetary and Space Exploration Program”, Special Lecture of Public Policy and Opinion Cell of IIT Kanpur, on 27-08-2022.
2. “Indian Planetary and Space Exploration Program”, Distinguish Lecture Series of the Central University of Rajasthan, on 02-09-2022.
3. “Emerging Scientific Missions”, Plenary Talk on Engineers Conclave 2022, Liquid Propulsion System Centre(LPSC), Valiamala, Thiruvananthapuram, on 14-10-2022.
4. “Indian Planetary Missions: Science and Challenges”, Plenary Talk on National Conference on Akash for Life, Uttaranchal University, Dehradun, on 06-11-2022.
5. “Distinguished Alumni Lecture”, Lucknow University, Lucknow, on 26-11-2022.
6. “Distinguished Inaugural Lecture”, Atal Research and Incubation Conclave (ARIC22), Atal Bihari VajpayeeIndian Institute of Information Technology and Management (ABV-IIITM), on 09-12-2022.
7. “Indian Planetary Missions”, Distinguish Lecture in Manohar Parrikar Vidnyan Mahotsav 2022, Goa, on 13-12-2022.
8. “Indian Planetary and Space Missions”, Plenary Talk on 108^{th} Indian Science Congress, R.T.M. Nagpur University, Nagpur, on 04-01-2023.
9. “Keynote Lecture”, 39^{th} Annual Symposium on Space Science & Technology, ISROIISc Space Technology Cell, IISc, Bangalore, on 16-01-2023.
10. “Plenary Talk”, India International Science Festival (IISF-2023), Maulana Azad National Institute of Technology (MANIT), Bhopal, M.P., on 22-01-2023.
11. “Invited Plenary Lecture”, Indian Scientist Contribution for Development of India, Gujarat Vigyan Sammelan 2023, Science City, Ahmedabad, on 15-02-2023.
12. “Institute Special Talk”, Indian Institute of Science Education and Research (IISER), Trivandrum, on 24-02-2023.
13. “Space Science Day”, Talk Celebrating Prof. UR Rao Birthday, Karnataka Science and Technology Academy (KSTA), DST - Govt. of Karnataka, on 10-03-2023.
14. “Inaugural Key-Note Lecture”, National Student Research Convention 2023, Ganpat University, on 16-03-2023.
15. “Space Leadership Development Programme (SLDP-2023)”, ISRO HQ, on 13-02-2023.
16. “Inaugural Speech”, TEDx Event of Ahmedabad International School at J.B. Auditorium, Ahmedabad Management Association, on 08-10-2022.
17. “Interview with PWC - IN-SPACe”, Insights required from Academia to formulate Decadal Vision and Strategy for Indian Space Ecosystem, on 20-02-2023.
18. “Indian Planetary Mission”, Celebration of National Science Week, VIT, Bhopal, on 03-03-2022.
19. “Planetary Mission of India”, Online Interactive Session at Certificate Course on Space Technology and Applications, IIRS, Dehradun, on 26-05-2022.
20. “Interactive Talk with Young President Organisation (YPO)”, Gujarat Chapter members at PRL, on 29-07-2022.
21. “Planetary and Space Missions of India”, Public Lecture as part of SCOP-2022, PRL, Ahmedabad, on 29-09-2022.
22. “Indian Planetary and Space Missions”, 7^{th} National Symposium on Shock Waves (NSSW-2023), PRL, Ahmedabad, on 15-02-2023.

D. Pallamraju

23. “A brief overview of PRL”, National Science Day, PRL, on 24-02-2023.

Srubabati Goswami

24. “Monitoring and promotion of diversity in Asian landscape”, A webinar given at the Outreach, Education and Diversity parallel session of the conference LHCp 2022, on 16-05-2022.
25. “From an Impossible Dream to the Unreachable Stars : the story of the neutrino”, A colloquium given at JNU, Delhi, on 20-02-2023.
26. “The Invisible Nu-World”, A colloquium given at Raman Research Institute, Bangalore, on 08-03-2023.

Varun Sheel

27. “Planetary Science: Climate on Other Planets”, University of Petroleum and Energy Studies (UPES), Dehradun, on 18-08-2022.

Neeraj Srivastava

28. “A visit to the Moon”, International Moon Day Celebrations, Shree Narayana Guru Vidyalaya, Ahmedabad Explore the Space, Space Education & Research Foundation (SERF), Gujarat, on 20-07-2022.

S. Vijayan

29. “Talk on International Moon Day”, Shree Narayana Guru Vidyalaya School, Ahmedabad, on 20-07-2022.

Narendra Ojha

30. “World Ozone Day”, Awareness workshop on World Ozone Day, Doon University, Dehradun, on 16-09-2022.

31. “Atmospheric observations and modelling”, Navyug Vidyalaya, Porbandar, on 21-01-2023.

S. Sharma

32. “’An expert on Joshimath land subsidence’”, NDTV India Humlog Program, on 08-01-2023.

Area Seminar by visitors

Dr. Kyung-Suk Cho

1. “Multi wavelength study of solar activities and KASI programs for Heliophysics”, Korea Astronomy and Space Science Institute (KASI), South Korea, on 20-10-2022

Prof. Rajdeep Dasgupta

2. “Maurice Ewing Professor of Earth Systems Science, Rice University, USA”, Maurice Ewing Professor of Earth Systems Science, Rice University, USA, on 04-11-2022

Prof. C. Woehler

3. “Remote sensing studies of planetary regolith surfaces: Topographic mapping, reflectance spectroscopy, photometry, polarimetry, thermal modelling, machine learning - and linking them all up”, Image Analysis Group, Dortmund University of Technology, Germany, on 08-02-2023

Dr. Ramon Brasser

4. “The Solar System’s Great Divide”, Research Centre for Astronomy and Earth Sciences, Budapest, Hungary, on 01-03-2023

Dr. Ajai Kumar

5. “Application of cold atmospheric plasma produced redox active species in aerospace, agriculture and medical therapy”, Institute for Plasma Research, Gandhinagar, on 06-02-2023

Dr. Fazlul I. Laskar

6. “How SpaceX lost 38 out of the 49 Starlink satellites launched on 3rd February 2022?”, Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, USA, on 19-12-2022

Dr. Maheswar Rupakheti

7. “Understanding optical and radiative properties of light-absorbing aerosols in the central Himalayan/ Tibetan Plateau region”, Institute for Advanced Sustainability Studies, Potsdam, Germany, on 15-11-2022

Dr. Shovan Dutta

8. “Controllable long-range entanglement in a lossy qubit array”, Max Planck Institute for the Physics of Complex Systems, Dresden, Germany, on 04-04-2022

Dr. Anirban Lahiri

9. “Chiral limit of QCD: interests and relevance”, University of Bielefeld, Bielefeld, Germany, on 18-04-2022

Dr. Vivek Mishra

10. “Disorder, strong correlations and unconventional superconductors”, Kavli Institute of Theoretical Sciences, Beijing, China, on 14-06-2022

Dr. Chayan Majumdar

11. “Beyond Standard Model : A left-right theory approach”, Department of Physics, Indian Institute of Technology, Bombay, on 16-06-2022

Dr. Akanksha Bhardwaj

12. “Improved Constraints on Effective Top Quark Interactions using Edge Convolution Networks”, University of Glasgow, UK, on 14-07-2022

Dr. Manoj Kumar

13. “Phase transitions and critical phenomena in a disordered Potts model”, Institute of Physics, Chemnitz University of Technology, Germany, on 29-08-2022

Dr. Satyaki Kar

14. “Quantum Oscillations in Nodal-line semimetals”, Department of Physics, AKPC Mahavidyalaya, Bengai, Hooghly, West Bengal, on 30-08-2022

Dr. Raghuveer Garani

15. “Condensed dark matter with a Yukawa interaction”, INFN-Florence, Italy, on 20-09-2022

Dr. Soumita Pramanick

16. “A scotogenic $S3$ symmetric model for realistic neutrino mixing and generation of small yukawa couplings naturally from trans-Planckian asymptotic safety”, National Centre for Nuclear Research, Warsaw, Poland, on 22-09-2022

Dr. Jacky Kumar

17. “Explorations of physics at different scales”, Technical University of Munich, Germany, on 18-10-2022
18. “Key Aspects of EFTs”, Technical University of Munich, Germany, on 19-10-2022

Dr. Debmalya Chakraborty

19. “Three way interplay of strong correlations, topology, and disorder in high temperature superconductors”, Department of Physics and Astronomy, Uppsala University, Sweden, on 09-11-2022

Prof. Sarira Sahu

20. “Deciphering the ~ 18 TeV photons from GRB 221009A”, Instituto de Ciencias Nucleares, UNAM, Mexico City, on 05-01-2023

Dr. Anish Ghoshal

21. “Dynamical Generation of Dark Matter and Electroweak Scales”, University of Warsaw, Poland, on 01-02-2023

Dr. Pinaki Banerjee

22. “Modern Scattering Amplitude Methods for Particles and Strings”, Institute for Advanced Study, Princeton, on 27-02-2023

Dr. Ankur Das

23. “Topological Semimetals beyond regular”, Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot, Israel, on 01-03-2023
24. “Bosonization, Chiral Lüttinger Liquid, Spin chain and Quantum Hall”, Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot, Israel, on 02-03-2023

Dr. Manibrata Sen

25. “Reviving the sterile neutrino dark matter with neutrino secret self-interactions”, Max-Planck-Institut fr Kernphysik, Heidelberg, Germany, on 16-03-2023

Prof. Sreerup Raychaudhuri

26. “Evolution of Modern Science in India”, Department of Theoretical Physics, Tata Institute of Fundamental Research, Mumbai, on 04-08-2022

Prof. Arti Garg

27. “Many-body Localization: Recent Advancements and Puzzles”, Theory division, Saha Institute of Nuclear Physics, Kolkata, on 18-08-2022

Prof. Ashoke Sen

28. “Classical gravitational radiation from soft theorem”, International Centre for Theoretical Sciences, Bengaluru, on 01-09-2022

Prof. Krishnendu Sengupta

29. “Superconductivity: A phenomenon with many facets”, Indian Association for the Cultivation of Science, Kolkata, on 15-09-2022

Prof. A. K. T. Assis

30. “Webers Electrodynamics”, University of Campinas, Brazil, on 29-09-2022

Prof. Klaus Mølmer

31. “From Quantum Optics to Bits and Pieces”, Niels Bohr Institute, University of Copenhagen, Denmark, on 08-12-2022

Prof. Yuval Gefen

32. “Measuring Entanglement in Electronic Interferometers”, Department of Condensed Matter Physics, Weizmann Institute of Science, Israel, on 07-02-2023

Technical/ Scientific talk given in Hindi

1. Ms. Sonam Jitarwal

``शुक्र ग्रह पर बिजली मापन हेतु उपकरण (LIVE) के लिए विभिन्न एंटीना विन्यासों का तुलनात्मक विश्लेषण",
Inter Centre Technical Hindi Seminar, SAC, Ahmedabad, 07-04-2022.

2. Dr. Jayesh P. Pabari

``शुक्र गृह की आकाशीय बिजली की संभावना और उसके अध्ययन का उपकरण",
Inter Centre Technical Hindi Seminar, SAC, Ahmedabad, 07-04-2022.

3. Prof. D. Pallamraju

``अंतररक्ष मौसम की समझ: पृथ्वी पर संवहनीयता सुप्रनप्रित करने के लिए अत्यावश्यक",
World Space Week, PRL, Ahmedabad, 04-10-2022.

4. Dr. Narendra Ojha

``वायुमंडलीय मॉडलिंग में सुदूर संवेदन के अनुप्रयोग, भारतीय परिप्रेक्ष्य में ग्रहीय अन्वेषण एवं समानव अंतरिक्ष कार्यक्रम", हिंदी तकनीकी संगोष्ठी 2022, सैक, अहमदाबाद, 07-04-2022.

Student Training

Astronomy and Astrophysics

1. Kishan Malaviya, St Xaviers college, Ahmedabad, “Image simulation of astronomical Sources”, from January 2022 to March 2023, [Supervisor: Shashikiran Ganesh].
2. Priyanka Khandelwal, Dept., of Physics, Electronics and Space Sciences, Gujarat University, Ahmedabad, “Test and Evaluation of Detectors in IR and Visible Region For Astronomical Polarimetric Applications”, from January 2023 to April 2023, [Supervisor: Shashikiran Ganesh].
3. Akshat Trivedi, Birla Vishvakarma Mahavidyalaya, Anand, Gujarat, “Astronomical Large Data Reduction: Data Archival Pipeline”, from January 2023 to April 2023, [Supervisor: Shashikiran Ganesh].
4. Aastha Gupta, Birla Vishvakarma Mahavidyalaya, Anand, Gujarat, “Astronomical large data reduction: GUI for EMPOL data analysis”, from January 2023 to April 2023, [Supervisor: Shashikiran Ganesh].
5. Sameer Patidar, Indian Institute of Space Science and Technology, Thiruvananthapuram,, “Understanding Evolution Processes of Star Clusters using Gaia”, from May 2022 to July 2022, [Supervisor: Manash Samal].
6. Jayesh Kumar Jaiswa, IISc Bangalore, “Searching signatures of star-formation in SFO 62 cloud using Gaia”, from May 2022 to July 2022, [Supervisor: Manash Samal].
7. Rajarshi Chaudhury, Indian Institute of Science Education and Research Bhopal, “Study of Spectral Properties of Active Galactic Nuclei”, from May 2022 to July 2022, [Supervisor: Veeresh Singh]].
8. Mumlesh Sawasiya, National Institute of Technology, Warangal,, “The Designs of an Ultra-Violet Telescope and its back-end Spectrometer”, from May 2022 to July 2022, [Supervisor: Mudit K. Srivastava].
9. Nishant Patel, Indian Institute of Space Science and Technology - Thiruvananthapuram, “Photometric and Spectral Evolution of Novae”, from June 2022 to July 2022, [Supervisor: Mudit K. Srivastava].

Solar Physics

10. Varun Kelkar, Fergusson College, Pune, “3D reconstruction and arrival time prediction of geo-effective CMEs”, from June 2022 to July 2022, [Supervisor: Nandita Srivastava].
11. Shanmugha Balan, BITS, Pilani, “A Complete PFSSPY and SCS-based Magnetic Field Extrapolation and Tracing Code”, from Sept 2022 to Feb 2023, [Supervisor: Nandita Srivastava].
12. Ms. Parvathy S, CMS college, Kottayam, MG University, Kerala, “Designing of Optical Filters for Solar Observations”, from May 2022 to July 2022, [Supervisor: A Raja Bayanna].

Space and Atmospheric Sciences

13. Shravani Patil, Kasturba Walchand College, Sangli, Maharashtra, “Dispersive elements in Optics”, from Mar to May, 2023, [Supervisor: D. Pallamraju].
14. Isha Mahuvakar, St. Xavier’s college, “Characterization of Optical Interference Filters”, from Jun to Jul, 2022, [Supervisor: D. Pallamraju].
15. Komal, PRL, “Investigations of the ionospheric ion-drifts as measured by ICON satellite”, from Jan to Apr, 2023, [Supervisor: D. Pallamraju].
16. Ashish Kumar Mandal, PRL, “Optical Spectrographs for Aeronomy Studies”, from May to Jul, 2022, [Supervisor: D. Pallamraju].
17. Aparupa Apsara Baruah, Dibrugarh University, “Spatial inhomogeneity of the interplanetary magnetic field based on the measurement from the halo orbit around the first Lagrangian point of the Sun-Earth System”, from Apr to Jun, 2022, [Supervisor: Dibyendu Chakrabarty].
18. Saptarshi Lohia, Indian Institute of Space Science and Technology, Trivandrum, “Air-Sea Gas Transfer and Parameterization Techniques”, from May to Jul, 2022, [Supervisor: Lokesh Kumar Sahu].
19. Chandan Kumar Sahu, National Institute of Science Education and Research, Bhubaneswar, “Study of Atmospheric Clouds and Precipitation over Ahmedabad”, from May to Aug, 2022, [Supervisor: Som Kumar Sharma].
20. Amisha Rana, Banasthali Vidyapith, Rajasthan, “Development of an algorithm for investigation of Earth Atmosphere”, from Jan to Jun, 2022, [Supervisor: Som Kumar Sharma].
21. Muskan Jain, Banasthali Vidyapith, Rajasthan, “Development of an algorithm for investigation of Earth Atmosphere”, from Jan to Jun, 2022, [Supervisor: Som Kumar Sharma].
22. Harshita Gehlot, St. Xavier’s College, Ahmedabad, “Study of Atmospheric Clouds over Ahmedabad”, from May to Aug, 2022, [Supervisor: Som Kumar Sharma].
23. Juhi Trivedi, St. Xavier’s College, Ahmedabad, “Study of Atmospheric Clouds over Ahmedabad”, from May to Aug, 2022, [Supervisor: Som Kumar Sharma].

24. Mohammad Abdul Barek, SAS-12 Course, CSSTEAP, “Study of Atmospheric Convective Clouds using Satellite based Observations”, from Jun to Jul, 2022, [Supervisor: Som Kumar Sharma].

25. Munkhtsetseg Ganzorg, SAS-12 Course, CSSTEAP, “Study of Atmospheric Clouds using Ground-based Observations and Reanalysis Datasets”, from Jun to Jul, 2022, [Supervisor: Som Kumar Sharma].

26. Yogesh Patel, St. Xavier’s College, Ahmedabad, “Design and development of open-loop sun tracking instrument”, from Jan 2022 to Apr 2023, [Supervisor: Harish Gadhavi].

27. Vaibhav Trivedi, Fergusson College, Pune, “Validation of ECHAM-HAMMOZ AOD against observations”, from May to Jun, 2022, [Supervisor: Harish Gadhavi].

28. Sayanee Haldar, National Institute of Technology, Rourkela, “Solar flare effects on the Earth’s upper atmosphere”, from 10 May to 10 Jul, 2022, [Supervisor: K. Venkatesh].

29. Mohit Singh Choudhary, IIT Guwahati, “Airglow Processes in the Upper Atmosphere”, from May to Jul, 2022, [Supervisor: Ravindra Pratap Singh].

30. Kiran, PRL, “Grating based Imaging Spectrograph for OH and O2 intensity and temperature measurements”, from May to Jul, 2022, [Supervisor: Ravindra Pratap Singh].

31. Amey S. Wairagade, Silver Oak College of Engineering and Technology, Ahmedabad, “Office Management”, from Apr to May, 2022, [Supervisor: Atul Manke].

32. Aakash Gupta, PRL, “Velocity Distribution Function of ions in Solar Wind”, from Aug to Dec, 2022, [Supervisor: Dibyendu Chakrabarty].

33. Komal, PRL, “The velocity distribution function of electrons in solar wind”, from Aug to Dec, 2022, [Supervisor: Dibyendu Chakrabarty].

34. Ravi Chaurasiya, USO, PRL, “Characterization of Solar Energetic particles (SEP) from 1 AU”, from May to Jul, 2022, [Supervisor: Dibyendu Chakrabarty].

35. Neeraj Tiwari, PRL, “Moments of Plasma Velocity Distributions (ASPEX: SWIS)”, from May to Jul, 2022, [Supervisor: Dibyendu Chakrabarty].

Planetary Sciences

36. Moinak Sinha, Delhi University, “A comprehensive study about sedimentary deposits in the Jezero crater by comparing orbiter and rover data.”, from 15 May 2022 to 15 June 2022, [Supervisor: Amit Basu Sarbhadhikari].

37. Harsh Thakur, Indian Institute of Science, Bengaluru, “Magmatic history of Asteroid 4 Vesta”, from May 2022 to June 2022, [Supervisor: Dwijesh Ray].

38. Chetna Sharma, Panjab University, Chandigarh, “Analysis of Dust Impact Signals”, from 22 July 2022 to 9 September 2022, [Supervisor: J. P. Pabari].

39. Chandani P. Pabari, St. Xaviers College, Ahmedabad, “Variation of Ar-40 in Lunar Exosphere”, from 13 May 2022 to 12 July 2022, [Supervisor: J. P. Pabari].

40. Shivani Singh, B. V. M. Engg. College, Vallabh Vidhyanagar, “Prototype of plane parallel impact ionization dust detector”, from 27 December 2022 to 10 May 2023, [Supervisor: J. P. Pabari].

41. Janki Shah, L.D. College of Engineering, Ahmedabad, “Requirements for lightning prediction through AI/ML”, from 23 January 2023 to 31 May 2023, [Supervisor: J. P. Pabari].

42. Anushka Singh, National Institute of Technology, Patna, “Measurable Schumann Resonance using Mars Climate Database”, from 4 January 2023 to 30 June 2023, [Supervisor: J. P. Pabari].

43. Mahima Sakalle, Fergusson College, Pune, “Study of Schumann Resonance on Mars”, from 13 June 2022 to 5 August 2022, [Supervisor: J. P. Pabari].

44. Shweta Bhave, St. Xaviers College, Ahmedabad, “RAMSES: A Numerical Study Star Formation”, from Jan 2022 to April 2023, [Supervisor: Kinsuk Acharyya].

45. Chirag Sharma, IISER Bhopal, “Water Masers at High-Redshift Galaxies”, from May 2022 to June 2022, [Supervisor: Kinsuk Acharyya].

46. Ramnani Roshni Pratap Kumar, Gujarat University, “Machine Learning based hydroxyl signature detection utilizing M3 data from Chandrayaan -1”, from 01 Feb 2022 to 30 July 2022, [Supervisor: Megha Bhatt].

47. Sheth Rajvee Shailesh Kumar, Gujarat University, “Machine Learning based hydroxyl signature detection utilizing M3 data from Chandrayaan -1”, from 01 Feb 2022 to 30 July 2022, [Supervisor: Megha Bhatt].

48. Sreyasi Biswas, National Institute of Technology, Rourkela, “The contribution of transient lunar volcanism on lunar polar volatiles”, from 15 May 2022 to 15 July 2022, [Supervisor: Anil Bhardwaj and Megha Bhatt].

49. Mayand Dangi, Indian Institute of Technology Delhi, “Analysis and Characterization of Lunar Polar Regions Using Mini-RF and DFSAR data”, from 13 May 2022 to 15 July 2022, [Supervisor: Megha Bhatt].

50. Virang Lad, Physics student of Department of Physics and Electronics, St. Xaviers College, Ahmedabad, “Reflectance Spectroscopy of Planetary Analogues under simulated conditions”, from Jan 2022 to June 2022, [Supervisor: Neeraj Srivastava].

51. Charmi Golaviya, M.S. University, Baroda, “Lab reflectance spectroscopy of moon analogue (JSC-1A)”, from Jan 2022 to June 2022, [Supervisor: Neeraj Srivastava].

52. Saman Shakeel, Department of Remote Sensing and GIS Applications, Aligarh Muslim University, India, “Impact-ejected boulders featuring tracks on the Moon”, from 01 Feb 2023 to 31 May 2023, [Supervisor: Rishitosh K. Sinha].

53. Alik Mondal, Bhaskaracharya College of Applied Sciences, Delhi University, “Chandrayaan-2 OHRC image enhancement using AI ML”, from 01 Feb 2023 to 31 May 2023, [Supervisor: Rishitosh K. Sinha].

54. Mishal Mehta, St. Xaviers College, Ahmedabad, “MAVEN-NGIMS & MOM-MENCA data analysis”, from January 2022 to September 2022, [Supervisor: Shiv Kumar Goyal].

55. Debayan Rakshit, Pandit Deendayal Energy University, Gandhinagar, “Python based data processing for particle detectors”, from January 2022 to May 2022, [Supervisor: Shiv Kumar Goyal].

56. Sakshi Jagani, Indus University, Ahmedabad, “Python based data processing for particle detectors”, from January 2022 to May 2022, [Supervisor: Shiv Kumar Goyal].

57. Nupoor Chotaliya, St. Xaviers College, Ahmedabad, “Modelling and Characterization of Silicon Photomultiplier Detectors”, from January 2023 to June 2023, [Supervisor: Shiv Kumar Goyal].

58. Mansi Soni, St. Xaviers College, Ahmedabad, “Modelling and Characterization of Silicon Photomultiplier Detectors”, from January 2023 to June 2023, [Supervisor: Shiv Kumar Goyal].

59. Akash Yadav, National Institute of Technology Patna, Bihar, “Deleterious Satellite Charging and Possible Mitigation Schemes”, from January 2022 to May 2022, [Supervisor: Sanjay Kumar Mishra].

60. Ayushi Bhatt, Indian Institute of Technology Gandhinagar, “Velocity Distribution of the Electrostatically Detached Dust Particles over Sunlit Locations on Moon (Online)”, from January 2022 to May 2022, [Supervisor: Sanjay Kumar Mishra].

61. Nikhil Anand, NISER Bhubaneshwar, Odissa, “RF Propagation and Reflections from the Subsurface Cavities”, from May 2022 to June 2022, [Supervisor: Anil Bhardwaj and Sanjay Kumar Mishra].

62. Chahat Kaushik, AMOPH, PRL, “Detection of Charged Particles in Semi-Conductor Radiation Detectors”, from 17 May 2022 to 5 July 2022, [Supervisor: Shanmugam M].

63. Animay Tiwari, Institute of Technology Gopeshwar, “Study on Optimization of Impact Plasma Detection Area of Dust Detector”, from 11 Feb 2022 to 31 May 2023, [Supervisor: Srirag N. Nambiar].

64. Thahira U, Bharathidasan University, Trichy, “Glacial lakes on Mars and earth”, from May 2022 to ongoing, [Supervisor: S Vijayan].

65. Aditya Dharaiya, Savitribai Phule Pune University, “Martian impact craters”, from December 2022 to ongoing, [Supervisor: S Vijayan].

66. Mithil Rajput, Indian Institute of Technology Kharagpur, “Numerical modelling of impact craters”, from April 2022 to ongoing, [Supervisor: S Vijayan].

67. Raya Rahul, Indian Institute of Space Science and Technology, Trivandrum, “Ballistic analysis of impact crater ejecta”, from June 2022 to ongoing, [Supervisor: S Vijayan].

68. Ayan Chatterjee, North Eastern Hill University, “Understand the role of fluvial channels on Mars”, from May 2022 to July 2022, [Supervisor: S Vijayan].

Geosciences

69. Aditya Dam, Delhi Technological University, New Delhi, “Formation and composition of aerosols in Asian Tropopause Aerosol Layer and their impacts on climate change”, from May, 2022 to July, 2022, [Supervisor: N. Rastogi].

70. Namrata Biswas, Presidency University, Kolkata, “Chronology of a Dandak cave stalagmite”, from May, 2022 to July, 2022, [Supervisor: M.G. Yadava & P. Nayak].

71. Arnab Seal, Presidency University, Kolkata, “Establishing protocols for Peat dating”, from May, 2022 to July, 2022, [Supervisor: M.G. Yadava].

72. Neha, Banasthali University, “Marine carbon dioxide removal techniques”, from May, 2022 to July, 2022, [Supervisor: A. Singh].

73. Anu M, IISER Bhopal, “Ocean alkalinity enhancement”, from Nov, 2022 to Dec, 2022, [Supervisor: A. Singh].

74. Krishnaprsad A A, Manipal Institute of Technology, “Mineral Dust deposition to the Western Arabian Sea: Marine sediment records”, from Jan, 2023 to April, 2023, [Supervisor: A.K. Sudheer].

75. Ankita Mukherjee, IIT Bhubaneswar, “Estimating Residence times of Groundwater in semi-arid regions of Gujarat”, from May, 2022 to July, 2022, [Supervisor: A.H. Laskar].

76. Sonal S. Gadankush, IISER, Pune, “Soil organic carbon dynamics in tropical Indian forests: investigation using radiocarbon and stable isotope ratios”, from Jun, 2022 to March, 2023, [Supervisor: A.H. Laskar].

77. Ronakkumar Maurya, St. Xavier’s College, Ahmedabad, “Precise measurement of trace elements, chemical separation and isotope analysis of chromium in geological reference materials”, from Jan, 2023 to May, 2023, [Supervisor: Y. Kadlag].

Atomic, Molecular and Optical Physics

78. Anjana Ajith, Dept. Of Geology & Environmental Science Christ College, Kerala, “Luminescence Dating”, from 10 May 2022 to 08 July 2022, [Supervisor: Naveen Chauhan].

79. Chinmay Anil Nawlakhe, Engineering Physics, IIST Thiruvananthapuram, Kerala, “Instrumentation and programming”, from 13 June 2022 to 22 July 2022, [Supervisor: Naveen Chauhan].

80. Parth Khanduri, Charotar University of Science and Technology(CHARUSAT) University, Changa, Gujarat, “Luminescence thermochronology basics”, from 30 May 2022 to 30 June 2022, [Supervisor: Naveen Chauhan].

81. Milan Bhatt, Charotar University of Science and Technology (CHARUSAT) University, Changa, Gujarat, “Luminescence thermochronology basics”, from 30 May 2022 to 30 June 2022, [Supervisor: Naveen Chauhan].

82. Tejaswi Kondhiya, Charotar University of Science and Technology(CHARUSAT) University, Changa, Gujarat, “Luminescence thermochronology basics”, from 30 May 2022 to 30 June 2022, [Supervisor: Naveen Chauhan].

83. Parth Khanduri, Charotar University of Science and Technology(CHARUSAT) University, Changa, Gujarat, “MSc. Dissertation in rock surface exposure dating”, from 01 August 2022 to 30 April 2023, [Supervisor: Naveen Chauhan].

84. Sanchayan Banerji, The National Institute of Science Education and Research (NISER), Bhubaneswar, Odisha, “Enhancement of Quantum efficiency of Quantum Emitters”, from 15 May 2022 to 15 July 2022, [Supervisor: Satyendra Nath Gupta].

85. Ajay Kumar, IIT Kanpur, “OAM Modes under Atmospheric Turbulence”, from 13 May 2023 to 15 July 2023, [Supervisor: Shashi Prabhakar].

86. Preeti Gangwani, SVNIT Surat, Gujarat, “Generating Pure High-Dimensional Entangled State”, from 09 January 2023 to 26 May 2023, [Supervisor: Shashi Prabhakar].

87. Pritikona Ghosh, Gobardanga Hindu College, West Bengal State University, “Hypervelocity impacts on icy bodies”, from May 2022 to July 2022, [Supervisor: Bhalamurugan Sivaraman].

88. Gaurav Vishwakarma, IIT Madras, Chennai, “1-propanol and water ice mixture on ism cold dust analogue”, from 04 July 2022 to 17 Jul 2022, [Supervisor: Bhalamurugan Sivaraman].

89. Deeptanshu Sheel, IISER Bhopal, Madhya Pradesh., “Laboratory astrochemistry”, from 19 December 2022 to 07 January 2023, [Supervisor: Bhalamurugan Sivaraman].

90. Tim Sandmann, Via (DAAD RISE Worldwide exchange student) Univ of Karlsruhe, Germany, “Origin of hydrogen chloride on Mars - Martian perchlorates”, from 01 August 2022 to 04 October 2022, [Supervisor: Bhalamurugan Sivaraman].

91. Vigneshwaran K, Government Arts College- Salem, “Chemical weathering and laterization of Sivagangai formation”, from January 2022 to May 2022, [Supervisor: Bhalamurugan Sivaraman].

92. Ann Mary Wilson, St. Xaviers College, Bengaluru, “VUV spectroscopy of ammonia ices”, from 25 August 2022 to 24 February 2023, [Supervisor: Bhalamurugan Sivaraman].

93. Aswin R, IISER Bhopal, MP, “Irreversible phase change in astrochemical ices”, from 15 October 2022 to 10 April 2023, [Supervisor: Bhalamurugan Sivaraman].

94. Sathiyaseelan, Kamaraj University, Madurai, “Ph.D final year”, from March 2022 to March 2022, [Supervisor: Bhalamurugan Sivaraman].

95. Pratik Saud, IIT Gandhinagar, “Ion trajectory simulation for development of Time-of-Flight (TOF) mass spectrometer and Velocity-Map- Imaging (VMI) spectrometer”, from 11 June 2022 to 10 July 2022, [Supervisor: Rajesh Kumar Kushawaha].

96. Rutik shanbhag, Goa University, Goa, “Design and Implementation of 4-Channel Orbital Angular Momentum (OAM) based Data Communication System for Multiplexing”, from 15 May 2022 to 15 June 2022, [Supervisor: Rajesh Kumar Kushawaha].

97. Kunal Vaze, Goa University, Goa, “Orbital Angular Momentum (OAM) Generation and characterization for Data Communication System”, from 15 May 2022 to 15 June 2022, [Supervisor: Rajesh Kumar Kushawaha].

98. Sneha N., The National Institute of Science Education and Research (NISER), Bhubaneswar, Odisha, “Investigating role of Atomic Basis Functions for High-Precision calculations”, from 15 May 2023 to 02 July 2023, [Supervisor: Prof. Bijaya Sahoo].

Theoretical Physics

99. Lagisetty Divyesh Krishna, Indian Institute of Science Education and Research, Bhopal, “Advanced Quantum Mechanics and Application to Neutrino Physics”, from 15 May, 2022 to 15 July, 2022, [Supervisor: Namit Mahajan].

100. Sayan Kumar Das, Indian Institute of Science Education and Research, Kolkata, “CP Violation in Neutral Kaon System”, from 15 May, 2022 to 15 July, 2022, [Supervisor: Namit Mahajan].

101. Ayushi Chakrabarty, Vellore Institute of Technology, “Evaluation of the Effectiveness of Autoencoders for Anomaly Detection: A Case Study”, from 1 July, 2022 to 30 July, 2022, [Supervisor: Partha Konar].

102. Kanika Gandhi, Birla Institute of Technology and Science, Pilani, “Variational Inference using Invertible Neural Networks”, from 15 April, 2022 to 15 July, 2022, [Supervisor: Partha Konar].

103. Prashant Sheladiya, MSU, Vododara, “Height resolved study of Cosmic rays intensity by using digital GM counter”, from 27 April, 2022 to 2 June, 2022, [Supervisor: Navinder Singh].

104. Rounak Chakraborty, Indian Institute of Technology, Kharagpur, “BCS Theory of Superconductivity”, from 10 May, 2022 to 15 July, 2022, [Supervisor: Paramita Dutta].

Dean’s Office

105. Dhwani Patel, Indus Institute of Technology and Engineering, Indus University, Ahmedabad, “Academic Information System”, from January 2023 to April 2023, [Supervisor: Dinesh Mehta].

106. Vanshilka Parikh, Indus Institute of Technology and Engineering, Indus University, Ahmedabad, “Academic Information System”, from January 2023 to April 2023, [Supervisor: Dinesh Mehta].

Division Visitor Details

Astronomy and Astrophysics

1. Dr. Sunil Chandra, South African Astronomical Observatory and Centre for Space Research, North-West University, South Africa, “Collaborative work”, from 08-12-2022 to 10-12-2022,[Seminar : “1. Vision of intelligent observatories, a boon for fast transient follow-up programs: Efforts at South African Astronomical Observatory (SAAO), Cape Town.

   2. Understanding the emission mechanisms and the particle acceleration in astrophysical jets”].

2. Dr. Kumar Venkataramani, California Institute of Technology, USA, “Collaborative work”, from 08-12-2022 to 10-12-2022,[Seminar : “earch for Near-Earth Objects using Zwicky Transient Facility”].

3. Dr. Siddharth Maharana, Institute of Astrophysics, Foundation for Research and Technology-Hellas (FORTH), Crete, Greece, “Scientific discussion”, from 15-03-2023 to 17-04-2023,[Seminar : “Design, Development and Performance Modelling of WALOP Polarimeters for PASIPHAE Survey”].

4. Dr. Yalia Divakara Mayya, National Institute of Astrophysics, Optics and Electronics (INAOE), Mexico, “Collaborative discussion”, from 22-01-2023 to 23-01-2023,[Seminar : “On the origin of a kiloparsec size superbubble in the JWST images of the phantom galaxy”].

5. Dr. Priyanka Chatruvedi, Thuringer Landessternwarte Tautenburg, Tautenburg, Germany, “Collaborative work”, from 30-01-2023 to 31-01-2023,[Seminar : “From hot Jupiters to super-Earths: Exoplanets and beyond”].

Solar Physics

6. Dr. Kyung-Suk Cho, Korea Astronomy and Space Science Institute (KASI), South Korea, “To explore future collaborative works in pace sciences between PRL and KASI”, from 18-10-2022 to 20-10-2022,[Seminar : “Multi wavelength study of solar activities and KASI programs for Heliophysics”].

Space and Atmospheric Sciences

7. Dr. Ajai Kumar, Institute for Plasma Research Gandhinagar India, “To give seminar”, from 06-02-2023 to 06-02-2023,[Seminar : “Application of cold atmospheric plasma produced redox active species in aerospace, agriculture and medical therapy”].

8. Dr. Fazlul I. Laskar, University of Colorado Boulder USA, “To give seminar”, from 19-12-2019 to 19-12-2019,[Seminar : “Laboratory for Atmospheric and Space Physics”].

9. Dr. Maheswar Rupakheti, Institute for Advanced Sustainability Studies Potsdam Germany, “To give seminar”, from 15-11-2022 to 15-11-2022,[Seminar : “Understanding optical and radiative properties of light-absorbing aerosols in the central Himalayan/ Tibetan Plateau region”].

Planetary Sciences

10. Prof. Rajdeep Dasgupta, Maurice Ewing Professor of Earth Systems Science, Rice University, USA, “Prof. Dasgupta visited PRL as part of his award for a chaired professorship by the Indian Academy of Sciences, Bengaluru”, from 03-11-2022 to 05-11-2022,[Seminar : “On the origins of life-essential volatile elements in differentiated rocky bodies in the Solar System”].

11. Dr. Alik S. Majumder, Assistant Professor, Indian Institute of Technology (Indian School of Mines, Dhanbad), “Collaborative research work (RESPOND basket)”, from 25-12-2022 to 07-01-2023.

12. Prof. C. Woehler, Image Analysis Group, Dortmund University of Technology, Germany, “For the polarimetric imaging of the Moon using Mount Abu telescope facility of PRL”, from 09-02-2023 to 21-02-2023,[Seminar : “Remote sensing studies of planetary regolith surfaces: Topographic mapping, reflectance spectroscopy, photometry, polarimetry, thermal modelling, machine learning - and linking them all up”].

13. Prof. Mahesh Anand, School of Physical Sciences, Open University, Milton Keynes, UK, “For exploring future scientific collaboration”, from 22-02-2023 to 23-02-2023,[Seminar : “PRL Ka Amrut Vyakhyaan: Apollo to Artemis: The Science and Exploration of the Moon”].

14. Dr. Ramon Brasser, Research Centre for Astronomy and Earth Sciences, Budapest, Hungary, “Scientific discussions and interaction with PRL scientists”, from 01-03-2023 to 01-03-2023,[Seminar : “The Solar System’s Great Divide”].

Geosciences

15. Dr. Dharmaveer Singh, Assistant Professor at Symbiosis Institute of Geo-informatics, Symbiosis International University, “visited to initiate a collaborative research in groundwater hydrology.”, from 05-12-2022 to 06-12-2022,[Seminar : “He also presented on ”Integrating Earth Observations with Isotopes and CGMs outputs in Water Resources Management under Changing Climate””].

Atomic, Molecular and Optical Physics

16. Gangi Reddy Salla, Under DST/ICPS/QuST project., “To perform experiments on speckles generated using OAM modes”, from 02-01-2023 to 12-01-2023.

17. Dr. Murthy Gudipathi, NASA, USA., “Scientific Visit”, from 07-12-2022 to 09-12-2022,[Seminar : “Water, Organics, Energy and Life on Earth and Beyond - With a Focus on Europa and Habitability”].

18. Dr Vinitha, Indian Institute of Space Science and Technology, Trivandrum, India, “Scientific Visit”, from 16-03-2023 to 25-03-2023,[Seminar : “Some Experiments of relevance for PAHs in the Solar System”].

19. Dr. Chemist Mabena, Senior Researcher, National Laser Center, CSIR, Pretoria, South Africa, “Collaborative research on quantum optics”, from 08-01-2023 to 26-01-2023,[Seminar : “Orbital angular momentum in atmospheric turbulence”].

20. Joshua Aaron Foley Comer, M. Sc. Student, Tel-Aviv University, Israel, “To participate in spatial entanglement experiments and interact with group research members in the lab of Prof. Ravindra Pratap Singh”, from 27-02-2023 to 03-03-2023.

Theoretical Physics

21. Dr. Vivek Mishra, Kavli Institute of Theoretical Sciences, Beijing, “Academic interaction and discussion”, from 14-06-2022 to 15-06-2022.

22. Dr. Akanksha Bhardwaj, University of Glasgow, UK, “Academic interaction and discussion”, from 11-07-2022 to 17-07-2022.

23. Dr. Satyaki Kar, AKPC Mahavidyalaya, West Bengal, “Academic interaction and discussion”, from 30-08-2022 to 31-08-2022.

24. Dr. Jacky Kumar, Technical University of Munich, Germany, “Academic interaction and discussion”, from 18-10-2022 to 20-10-2022.

25. Dr. Debmalya Chakraborty, Uppsala University, Sweden, “Academic interaction and discussion”, from 09-11-2022 to 11-11-2022.

26. Prof. Sarira Sahu, Instituto de Ciencias Nucleares, Mexico, “Academic interaction and discussion”, from 04-01-2023 to 06-01-2023.

27. Prof. Yuval Gefen, Weizmann Institute of Science, Israel, “Academic interaction and discussion”, from 06-02-2023 to 07-02-2023.

28. Dr. Pinaki Banerjee, Institute for Advanced Study, Princeton, “Academic interaction and discussion”, from 27-02-2023 to 27-02-2023.

29. Dr. Ankur Das, Weizmann Institute of Science, Israel, “Academic interaction and discussion”, from 01-03-2023 to 03-03-2023.

30. Dr. Chayan Majumdar, Middle East Technical University, Turkey, “Academic interaction and discussion”, from 05-12-2022 to 31-03-2023.

Astronomy and Astrophysics

Soft X-ray Spectral Diagnostics of Multi-thermal Plasma in Solar Flares

Solar flares are sudden releases of energy in the lower atmosphere of the Sun. The standard flare model, also known as the CSHKP model, has been successful in explaining several observed features of solar flares. However, multiple aspects such as the exact location of particle acceleration and heating and the acceleration mechanism still remain unspecified. Resolving these issues requires knowledge of the local plasma thermal and nonthermal particle distributions, which can be best obtained from the X-ray and EUV observations.

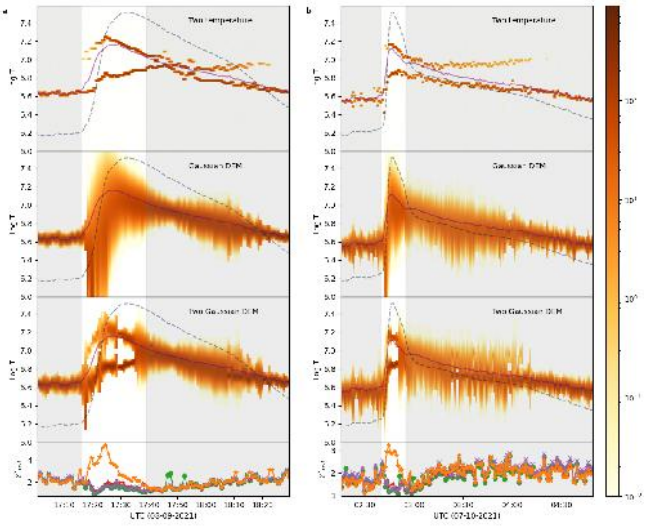


Figure 01: Differential Emission Measure (DEM) evolution during the 08-Sep-2021 flare (a) and the 07-Oct-2021 flare (b) obtained from spectral fitting. The top three panels show DEM with two-temperature, Gaussian, and double Gaussian models, respectively. Colour represents the EM in units of 10^{46} cm^{-3} MK^{-1}. The isothermal temperature measurements (purple solid line) and $1-15$ keV X-ray light curves (dashed line) are also shown for reference. The reduced chi-squared of the fit with two-temperature (green), Gaussian (red), and double Gaussian (purple) are shown in the lower most panels. The reduced chi-squared for the isothermal fit are shown in orange for comparison. Intervals when the isothermal and multi-thermal models have a similar fit to the spectra are greyed out and during the remaining period in the impulsive phase, the DEM models provide a much better fit to the spectra in comparison with the isothermal model.

The Solar X-ray Monitor (XSM) on board the Chandrayaan-2 mission provides broad- band disk integrated soft X-ray solar spectral measurements in the energy range of $1 - 15$ keV with high spectral resolution and time cadence. In this study, we analyze the X-ray spectra of three representative GOES C-class flares obtained with the XSM to investigate the evolution of various plasma parameters during the course of the flares. Using the soft X-ray spectra consisting of the continuum and well-resolved line complexes of major elements like Mg, Si, and Fe, we investigate the validity of the isothermal and multithermal assumptions on the high-temperature components of the flaring plasma. We find that the soft X-ray spectra during the impulsive phase of the high intensity flares are inconsistent with isothermal models and are best fitted with multi-thermal differential emission measure (DEM) distributions. Figure 1 shows the evolution of DEM during the course of flare obtained by modeling the XSM spectra with different DEM models. It can be seen that temperature distribution during the impulsive phase has to be either very broad or doubly peaked where the temperature of the hotter component rises faster than that of the cooler component. The two distinct temperature components observed in differential emission measure models during the impulsive phase of the flares suggest the presence of the directly heated plasma in the corona and evaporated plasma from the chromospheric footpoints. We also find that the abundances of low first ionization potential elements Mg, Si, and Fe reduce from near coronal to near photospheric values during the rising phase of the flare and recover back to coronal values during the decay phase, which is also consistent with the chromospheric evaporation consistent with the chromospheric evaporation

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This work is done in collaboration with G. Del Zanna, Y. K. Rao, H. E. Mason (DAMTP, University of Cambridge, UK).

(N. P. S. Mithun, S. V. Vadawale, B. Joshi, A. Sarkar, B. Mondal, P. Janardhan, and A. Bhardwaj)

Role of Small-scale Impulsive Events in Heating the X-Ray Bright Points of the Quiet Sun

Small-scale impulsive events, known as nanoflares, are considered one of the prime candidates that can keep the solar corona hot at its multimillion-Kelvin temperature. Individual nanoflares are challenging to detect with the current generation of instruments; however, their presence can be inferred through indirect techniques such as Differential Emission Measure (DEM) analysis. We employ this technique to investigate the possibility of nanoflare heating of the quiet corona during the minimum of solar cycle 24. We estimate the DEM of disk-integrated quiet Sun and X-ray bright points (XBP) using the observations from XSM onboard the Chandrayaan-2 orbiter and AIA onboard the Solar Dynamic Observatory. XBPs are found to be the dominant contributor to disk-integrated X-rays. XBPs consist of small-scale loops associated with bipolar magnetic fields. We simulate such XBP loops using the hydrodynamic model. The lengths and magnetic field strengths of these loops are obtained through a potential field extrapolation of the photospheric magnetogram. Each loop is assumed to be heated by random nanoflares having energy that depends on the loop properties. The composite nanoflare energy distribution for all the loops has a power-law slope close to -2.5 (blue

curve in Figure 2b). The simulation output is then used to obtain the integrated DEM (blue and brown points in Figure 2a). It agrees remarkably well with the observed DEM (black points in Figure 2a) at temperatures above 1 MK, suggesting that the nanoflare distribution, as predicted by our model, can explain the XBP heating.

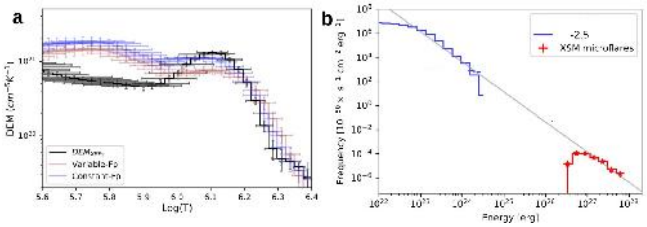

Figure 02: Panel a: Observed (black) and simulated (brown and blue) DEMs for the quiet Sun XPBs. Panel b: The nanoflares (blue) frequency distribution as a function of energies is compared with the observed XSM microflares (red) in the quiet Sun.

doi : https://doi.org/10.3847/1538-4357/acb8bb

This work is done in collaboration with J. A. Klimchuk (NASA Goddard Space Flight Center, USA), G. Del Zanna, H. E. Mason (DAMTP, University of Cambridge, UK), P. S. Athiray (NASA Marshall Space Flight Center, USA).

(B. Mondal, S. V. Vadawale, A. Sarkar, N. P. S. Mithun and A. Bhardwaj)

Multiwavelength Observations by XSM, Hinode, and SDO of an Active Region. Chemical Abundances and Temperatures

XSM carried out a very good observation of the Sun during the minimum of solar cycle 24. During this minimum, XSM observed the disk passage of AR 12759 when no other AR was present on the solar disk. Using the XSM observation, we derived the temperature and the chemical abundances of AR 12759 during its quiescent phases. The AR 12759 was also observed by other instruments; AIA onboard SDO, XRT and EIS onboard Hinode. To complement the XSM data, here, we perform a multi-wavelength study of quiescent AR 12759 using the data of XRT and EIS. The quiescent AR core emission of AR 12759 is found to have a distribution of temperatures and chemical abundances that did not change significantly over time. The XRT, EIS, and XSM observations are found to be consistent with each other.

AR 12759 produces a few small B-class flares studied in our earlier work (Mondal et al. (2021)). The flare SOL2020-04-06T05:48 is one of them. Using the observations of the AIA pass-bands, we have derived the multithermal plasma emission distribution (characterized by Emission Measure (EM) distribution) during the peak of the flare SOL2020-04-06T05:48, as shown in Figure 3. We forward modeled the XSM spectrum from the derived multithermal emission distribution and compared this modeled spectrum with the observed XSM spectrum (Figure 4). Both the modeled (red) and observed (black) spectra are found to match well, indicating a good agreement between the XSM and AIA.

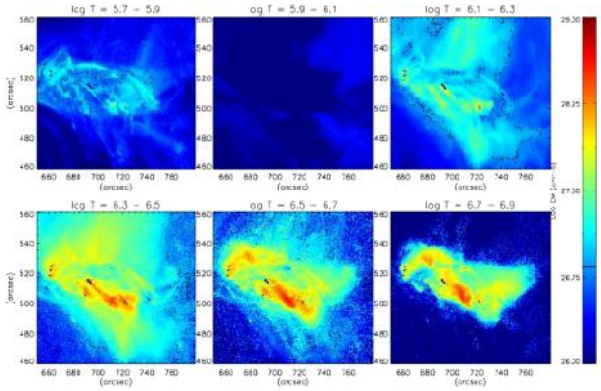

Figure 03: Emission Measure distribution during the peak of the flare SOL2020-04-06T05:48 in selected temperature bins. The EM distribution is shown for the AR core within which SOL2020-04-06T05:48 occur.

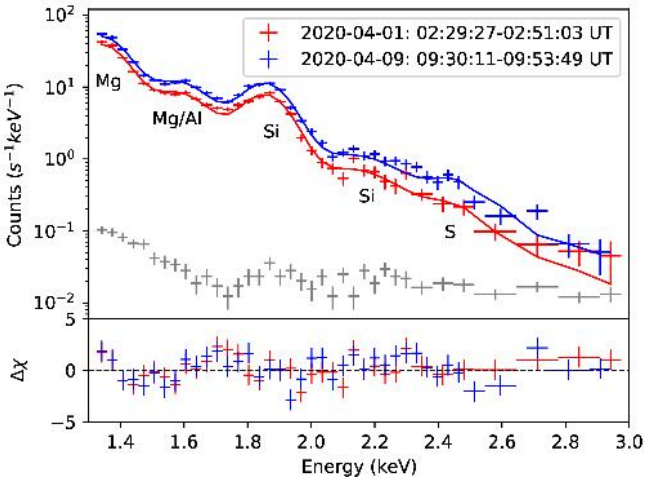

Figure 04: XSM averaged spectrum during the peak of SOL2020-04-06T05:48, with the predicted spectrum (red) derived from the average volume EM obtained from AIA pass-bands as shown in Figure 3. The grey colour represents the non-solar background spectrum observed by XSM.

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This work is done in collaboration with G. Del Zanna, Y. K. Rao, H. E. Mason (DAMTP, University of Cambridge, UK), K. K. Reeves (Harvard-Smithsonian Center for Astrophysics, USA).

(B. Mondal, N. P. S. Mithun, S. V. Vadawale, A. Sarkar, P. Janardhan, and A. Bhardwaj)

Role of spicules to heat the solar corona

Solar spicules are cold chromospheric jets that propagate through the lower solar atmosphere. A few of them reach a higher height, the corona, known as type II spicules. Recent high-resolution imaging and spectroscopic observations suggest that type II spicules can

heat the corona to its multi-million Kelvin temperature. We perform magnetohydrodynamic simulations to understand their role in heating the corona. We also produce observables, such as coronal spectral lines, that are usually used to infer about coronal heating. Our numerical simulations suggest prolonged hot emission is produced by preexisting material in the coroo nal loop heated by the shock and by thermal conduction from the shock. However, synthetic line profiles' shapes and Doppler shifts (Figure 5) show significant discrepancies with observations. Furthermore, the intensities dd erived from the spicule-generated corona are found to be much lower than the observed one, suggesting that if the observed intensities from the quiet Sun and active regions were solely due to type II spicules, oo ne would require several orders of magnitude more spicules to occur on the Sun than is reported in the literature.

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This work has been done in collaboration with J. A. Klimchuk of NASA, GSFC

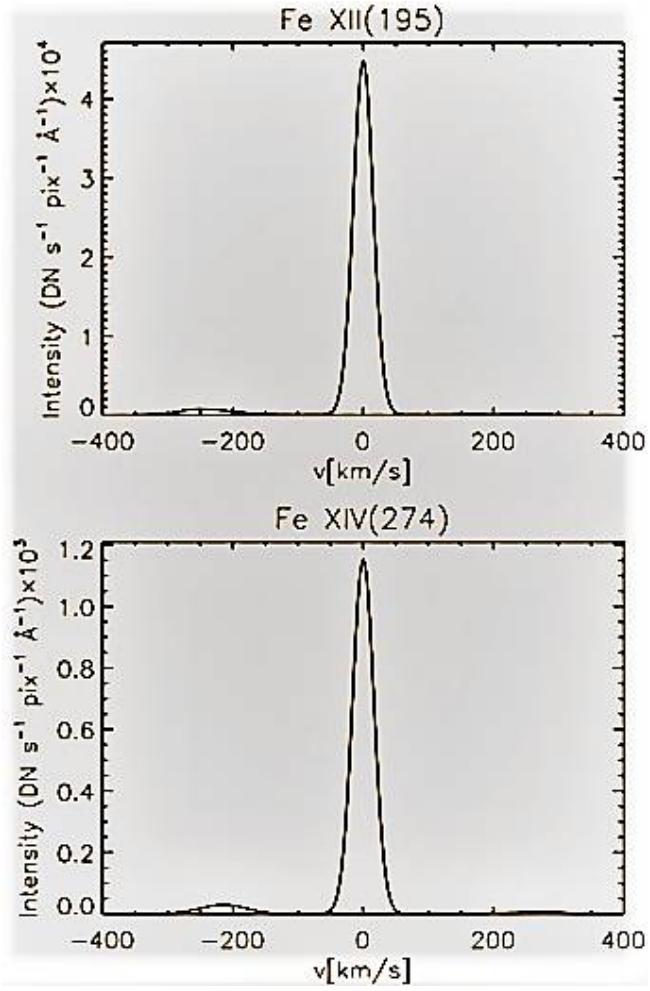

Figure 05: Simulated synthetic spectral lines assuming that the solar atmosphere is solely heated by spicules

(Shanwlee Sow Mondal and Aveek Sarkar)

Optical observations and dust modelling of comet 156P/Russell-LINEAR

The Jupiter family comet 156P/Russell-LINEAR has a short orbital period of 6.44 years but has not been extensively studied due to unfavourable viewing conditions. However, our team utilized spectroscopic, photometric, and polarimetric observations from two Indian observatories, the 1.2 m Mt. Abu and 2 m HCT Hanle, as well as dust modelling studies to analyze the physio-compositional properties of the comet. Our spectroscopic study revealed strong emissions from CN ($\Delta\nu$=0), C_3 (λ4050 Å), C_2 ($\Delta\nu$=+1), and C_2 ($\Delta\nu$=0) during both epochs of our observations, classifying the comet as typical based on the $Q(C_2)/Q(CN)$ production rate ratio.

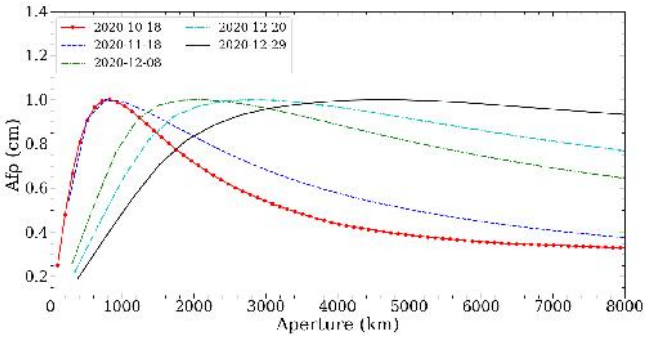

Figure 06: Comparison of the normalized Afρ profiles derived from a few selected imaging data observed using the HCT and IAC-80 telescope. The profile represented by the black solid line closely resembles the Afρ profile of a comet with a steady state outflow of dust.

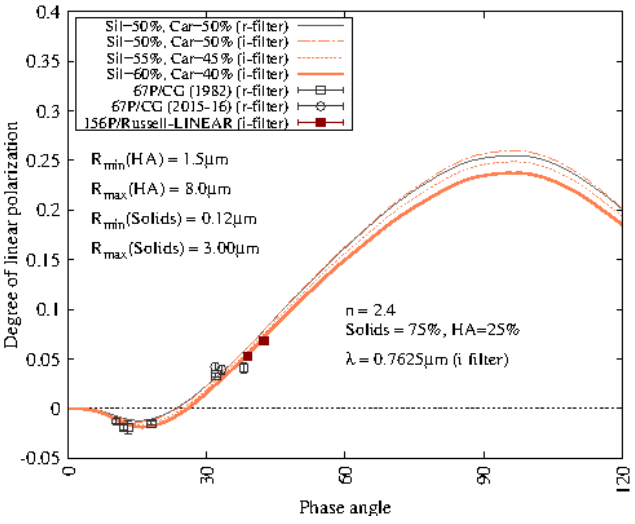

Figure 07: Best fit results for the comet 156P/Russell-LINEAR with the observations (dark-red solid squares). The light-red coloured lines indicate the best fit modelled polarization-phase curves obtained from this study in the sloan i filter and the grey solid line indicate the best fit model obtained for 67P from Halder and Ganesh (2021). The grey hollow squares/circles denote the previous observations of 67P in R filter.

The imaging data revealed the presence of powerful jets, and the dust emission had a non-steady state outflow due to these jets, which subsided in later epochs (see Figure 7) for variation in Afρ curve affected by the state of dust emission across multiple epochs). Our

polarimetric study at two different phase angles revealed a degree of polarisation comparable to Jupiter family comets at similar phase angles (see Figure 6). Localized variations in the polarisation values were seen within the coma, which could be a direct effect of the dust jets present. The dust modeling studies suggest the presence of a large amount of silicate/low absorbing material, and indicate the coma is dominated by large size grains with low porosity having a power law size distribution index of 2.4. Overall, our observations suggest 156P/Russell-LINEAR is similar to another Jupiter family comet, 67P/ChuryumovGerasimenko, in terms of its activity and dust properties.

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This work has been done in collaboration with Devendra Sahu, Tirupathi Sivarani, Dorje Angchuk (IIA, Bangalore), Miquel Serra-Ricart (Instituto de Astrofsica de Canarias, Spain) and Jose J. Chambo (Cometografia.es, Spain).

(Aravind K., Prithish Halder and Shashikiran Ganesh)

Peculiar motion of Solar system from the Hubble diagram of supernovae Ia and its implications for cosmology

Exploiting supernovae (SNe) Ia as standard candles, cosmological parameters have been derived, which suggested a Universe with accelerating expansion rate. One important element in these studies is that the observed heliocentric redshifts and magnitudes of SNe Ia are corrected for the peculiar velocity of the Solar system, 370 km s^{-1} along RA$= 168^{\circ}$, Dec$= -7^{\circ}$, derived from the Cosmic Microwave Background (CMB) dipole. On the other hand, a determination of the peculiar motion from the magnitude-redshift ($m_{\rm B} - z$) Hubble diagram of SNe Ia, gives a peculiar velocity $1.6 \pm 0.5 \times 10^3$ km s^{-1}, about four times larger than the CMB value, along a direction within $\lesssim 2\sigma$ of the CMB dipole. In last decade, Active Galactic Nuclei (AGN) dipoles with amplitudes much larger than the CMB dipole have been derived from the NRAO VLA Sky Survey (NVSS), TIFR GMRT Sky Survey (TGSS), the DR12Q data from the Sloan Digital Sky Survey III and the mid infra red AGN (MIRAGN) data. Such large values of peculiar motion would necessitate a fresh look at the determinations of cosmological parameters, which suggested an accelerating Hubble expansion.

Since a genuine solar motion would not depend upon the method or the dataset employed, large discrepancies seen among these dipole amplitudes could imply that these dipoles, including the CMB one, might not pertain to observer's peculiar motion. However, a common direction for these dipoles might indicate a preferred direction in the universe, implying an intrinsic anisotropy, in violation of the cosmological principle, a cornerstone of the modern cosmology. Moreover, any doubts on the cosmological principle will lead to similar doubts in the conventional interpretation of the magnitude-redshift diagram of SNe Ia to estimate cosmological parameters and the inferences drawn from them.

doi : https://doi.org/10.1093/mnras/stac1986

(A. K. Singal)

TOI 4603b, a Massive Giant Planet and most dense Exoplanet Discovered with PARAS Spectrograph

We have made an exciting discovery of a new, transiting massive giant exoplanet which is named as TOI 4603b or HD 245134b. Massive giant exoplanets are planets with a mass greater than four Jupiter masses.

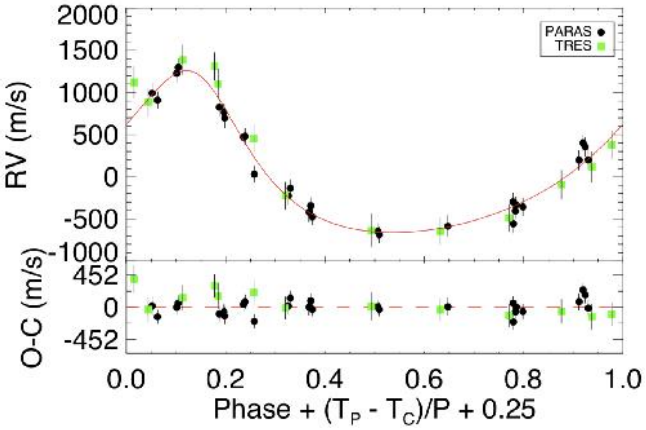

Figure 08: The obtained RVs from PARAS and TRES are plotted with respect to the $\sim$ 7.24 days orbital phase. The best-fitted RV model with EXOFASTv2 is represented by the red line, and residuals between the best-fit model and the data are shown in the bottom panel.

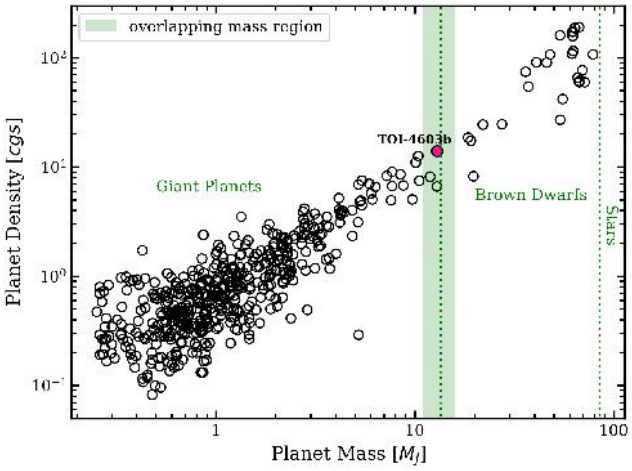

Figure 09: Planetary density as a function of planetary mass for transiting giant planets and brown dwarfs (0.25-85 M$_J$). The shaded area represents the overlapping mass region of massive giant planets and brown dwarfs based on the deuterium burning limit. The dotted lines are at M$_P$ = 13M$_J$ and M$_P$ = 85M$_J$, respectively. The position of TOI-4603 b is denoted by the magenta dot.

TOI-4603b is the exoplanet with the highest density of 14.1$\pm$1.6 g cm^{-3} among the zoo of exoplanets known to this date. It has a mass of 12.6$\pm$0.6 times Jupiter's Mass but a comparable size to that of Jupiter (1.04$\pm$0.04 Jupiter radius). The exoplanet orbits a subgiant F-type star every 7.24 days. Initially, NASA's TESS mission recognized the star TOI-4603 as a potential exoplanet host, but no information about the nature of the astrophysical body and its mass was available. The exoplanet discovery was made possible through the PRL Advanced

Radial-velocity Abu-sky Search (PARAS), a spectrograph at the PRL Gurushikhar Observatory (Figure 8). The PARAS observations were taken in 2022. This discovery is significant because the planet falls into the transition mass range of massive giant planets and low-mass rown dwarfs, i.e., 11 − 16 Jupiter mass, of which fewer than five are presently known (Figure 9). It is one of the most massive giant planets orbiting its host star in very close proximity ($<$ 0.09 AU) and is likely undergoing high-eccentricity tidal migration (e $\sim$ 0.3). Detecting such systems will provide valuable insights into the formation, migration, and evolution mechanisms of massive giant planets.

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This work was done in collaboration with Dr. Priyanka Chaturvedi of Thringer Landessternwarte Tautenburg, Germany.

(Akanksha Khandelwal, Rishikesh Sharma, Abhijit Chakraborty, Sanjay Baliwal, Neelam J.S. S. V. Prasad and Ashirbad Nayak)

IC 5146 Dark Streamer: The First Reliable Candidate of Edge Collapse, Hub-filament Systems, and Intertwined Sub-filaments

Massive OB-type stars (M $>$ 8 $M_{\odot}$) are known to play a significant role in the energy budget of galaxies via their UV radiation, wind, and supernova events. However, the physical processes governing the birth of massive stars are still not well understood. Dust and molecular filaments are actively involved in star formation processes (including massive stars). There are two popular scenarios when it comes to the role of filaments in star formation.

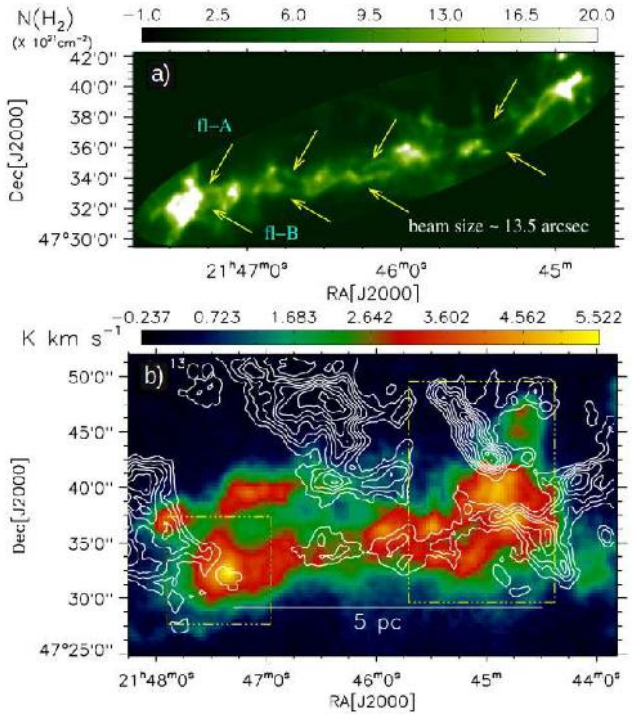

Figure 10: (a) Herschel column density map of IC 5146 Dark Streamer. The possible intertwined filaments (fl-A and fl-B) are marked by arrows. b) TRAO ^{13}CO(1-0) map of integrated intensity observed in velocities [3, 6] km s^{-1} (in color-scale) and in [0.8, 2.5] km s^{-1} (in contours).

One is called the "End-Dominated Collapse)" scenario, where isolated filaments collapse faster at their ends due to high gas acceleration. However, the observational signatures of this case are very limited in the literature. In another scenario concerning "Hub-Filament System", multiple filaments converge at a common place (i.e., filament-hub), that gain sufficient mass and density to form massive stars. The simultaneous existence of these processes is not well observed and understood. In this relation, we observationally studied a nearby (distance $\sim$600 pc) potential massive star-forming site, IC 5146 dark Streamer. High-resolution column density and temperature maps of the IC 5146 region revealed the presence of at least two intertwined sub-filaments, displaying a nearly double helix-like structure (see Figure 10a). High-column density regions are traced at the edges of the main filament, where hub-filament systems were found in previous studies. Using the ^{13}CO(1-0) and C^{18}O(1-0) line data cubes, the existence of two cloud components around 2 and 5 km s^{-1} towards the main filament is investigated (see Figure 10b). Overall, the interaction between these cloud components might have formed the observed hub-filament systems at the filament edges. Our results favor a scenario, which first predicts the formation of the main filament by a collision of two supersonic turbulent gas flows, and then the scenario favors the origin of the intertwined system of velocity-coherent substructures in the main filament due to residual turbulent motions and self-gravity. Taken together all the results, the IC 5146 Streamer can be recognized as the first reliable candidate of multiple processes of edge collapse, hub-filament systems, and intertwined sub-filaments together.

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This work was done in collaboration with A. Men'shchikov (Universit Paris-Saclay, Universit Paris Cit, CEA, CNRS, AIM, 91191, Gif-sur-Yvette, France), E. J. Chung (Department of Astronomy and Space Science, Chungnam National University, Daejeon, Republic of Korea), R. Devaraj (Dublin Institute for Advanced Studies, 31 Fitzwilliam Place, Dublin D02XF86, Ireland), C. W. Lee (Korea Astronomy and Space Science Institute, 776 Daedeokdae-ro, Yuseong-gu, Daejeon 34055, Republic of Korea), and T. Baug (Satyendra Nath Bose National Centre for Basic Sciences, Block-JD, Sector-III, Salt Lake, Kolkata-700 106, India.

(L. K. Dewangan, N. K. Bhadari and A. K. Maity)

Probing the role of ionized, dust, and molecular filaments in massive star-forming sites around l = 345.5 degree

In recent years, infrared and sub-millimeter data have revealed a wealth of bubbles and filamentary structures in star-forming regions, which are often associated with star-forming clumps, clusters of protostars, and massive stars (M $>$ 8 $M_{\odot}$). Understanding the role of filaments in the formation of dense star-forming clumps and the feedback of massive stars in their vicinity is still an open research topic in the area of star formation. In this context, numerous research studies on dust and molecular filaments have been conducted in star-forming sites, but only a limited number of studies have focused on ionized filaments. Ionized filaments traced by radio continuum maps may contain a series of ionized compact clumps excited by massive stars, supporting ongoing massive star formation activities. Hence, such targets offer to study not only the birth of massive stars but also the origin of ionized filaments. In this relation,

a multi-wavelength and multi-scale study of a wide area hosting massive star-forming regions around l = 345.5 degree is performed. This study reveals the ionized, dust, and molecular filaments in the target area (see Figure 11). The analysis of the near- and mid-infrared photometric data depicts noticeable protostars toward the filaments. The findings show the presence of networks of dust filaments associated with massive stars and clusters of protostars, and signatures of interacting molecular filaments. The existence of the ionized filaments seems to be explained by the combined feedback of massive stars. The molecular filaments favour the outcomes of the most recent model concerning the escape and the trapping of the ionizing radiation from an O star formed in a filament.

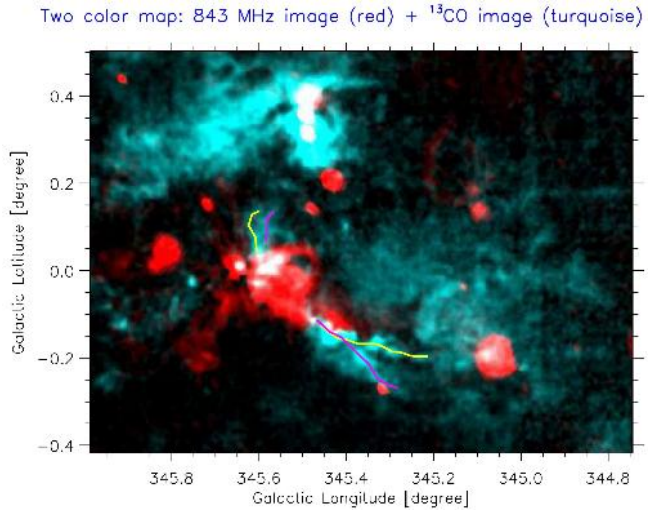

Figure 11: The panel shows a two-color composite image made using the SUMSS 843 MHz continuum emission (in red) and the ^{13}CO(J = 2–1) moment-0 map (in turquoise color). At least two elongated molecular laments are indicated by curves.

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This work was done in collaboration with L. E. Pirogov (Institute of Applied Physics of the Russian Academy of Sciences, 46 Ulyanov st., Nizhny Novgorod 603950, Russia.

(L. K. Dewangan, N. K. Bhadari and A. K. Maity)

New evidences in IRDC G333.73+0.37: colliding filamentary clouds, hub-filament system, and embedded cores

In recent years, with the availability of several ground- and space-based telescopes operating in infrared, sub-millimeter (mm), and radio wavelengths, significant progress has been made by researchers to probe the physical processes involved in forming massive stars ($\gtrsim$ 8 $M_{\odot}$). However, the birth of massive stars is not yet completely understood. To unravel the star formation process, a multi-scale and multi-wavelength study of the filamentary infrared dark cloud (IRDC) G333.73+0.37 has been carried out, which hosts previously known two H ii regions located at its center (see Figure 12a). Each H ii region is associated with a mid-infrared source, and is excited by a massive OB star. Two filamentary structures (length $>$ 6 pc) and a hub-filament system associated with one H ii region are investigated in absorption using the Spitzer 8.0 μm image (see Figure 12b). The ^{13}CO(J = 2–1) and C^{18}O(J = 2–1) line data reveal two velocity components (around $-$35.5 and $-$33.5 km s^{-1}) toward the IRDC, favouring the presence of two filamentary clouds at different velocities. Nonthermal (or turbulent) motions are depicted in the IRDC using the C^{18}O line data. The spatial distribution of young stellar objects (YSOs) identified using the VVV near-infrared data traces star formation activities in the IRDC. Low-mass cores are identified toward both the H ii regions using the ALMA 1.38 mm continuum map. The VLT/NACO adaptive-optics L′-band images show the presence of at least three point-like sources and the absence of small-scale features in the inner 4000 AU around YSOs NIR31 and MIR 16 located toward the H ii regions. The H ii regions and groups of YSO are observed toward the central part of the IRDC, where the two filamentary clouds intersect. A scenario of cloud-cloud collision or converging flows in the IRDC seems to be applicable, which may explain star formation activities including the hub-filament system and massive stars.

doi : https://doi.org/10.1093/mnras/stac967

This work was done in collaboration with L. E. Pirogov (Institute of Applied Physics of the Russian Academy of Sciences, Russia.

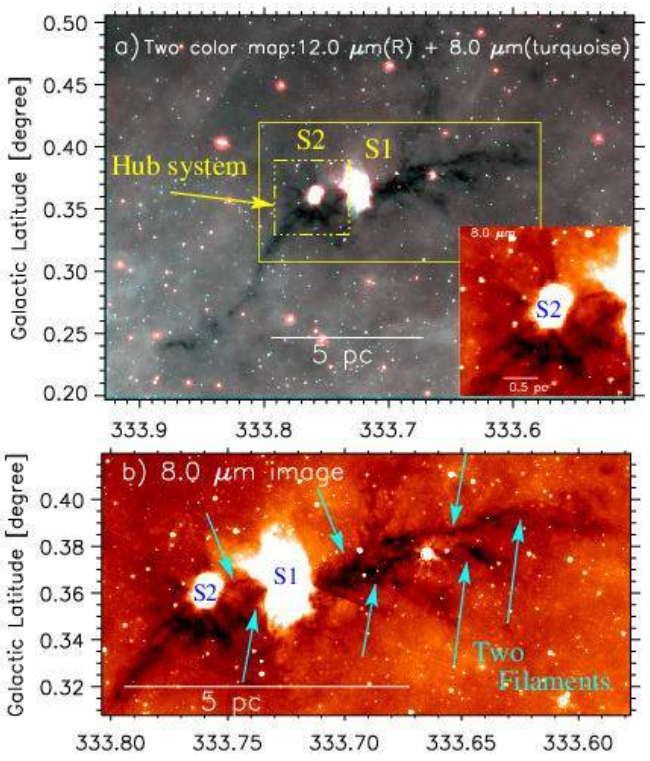

Figure 12:(a) The panel shows a two color-composite map of the filamentary IRDC G333.73+0.37. The color-composite map is produced using the WISE 12.0 μm (red) and Spitzer 8.0 μm (turquoise) images. Two distinct mid-infrared sources S1 and S2 are labeled in the panel. Using the Spitzer 8.0 μm image, the inset on the bottom right shows the region around S2 in zoomed-in view (see a dotted-dashed box in Figure 12a), revealing a hub-filament system toward S2. The solid box (in yellow) encompasses the area shown in Figure 12b. b) The panel presents the Spitzer 8.0 μm image of an area highlighted by a solid box in Figure 12a.

(L. K. Dewangan)

Simultaneous evidence of edge collapse and hub-filament configurations: A rare case study of a Giant Molecular Filament G45.3+0.1

Based on the analysis of infrared and sub-millimeter continuum maps, networks of filaments or hub-filament systems have been recognized as potential birthplaces of massive stars ($\gtrsim$ 8 $M_\odot$) and clusters of young protostars, and such hub-filament systems are commonly detected structures in our Galaxy. In addition to the hub-filament systems, isolated filaments associated with star-forming activities have also been identified in our Galaxy. In particular, concerning isolated filaments, the onset of the end-dominated collapse (or edge collapse) process has been reported in a very few star-forming sites (including HII regions powered by massive stars), where one exclusively expects two clumps/cores produced at the respective end of filament via high gas acceleration. These observed configurations directly manifest the role of filaments in star formation processes. However, no attempt has been made to explore the connection between these two distinct filament configurations. In this context, the present paper deals with two major star-forming complexes (i.e., G045.49+00.04 and G045.14+00.14; see Figure 13) located in the Aquila constellation.

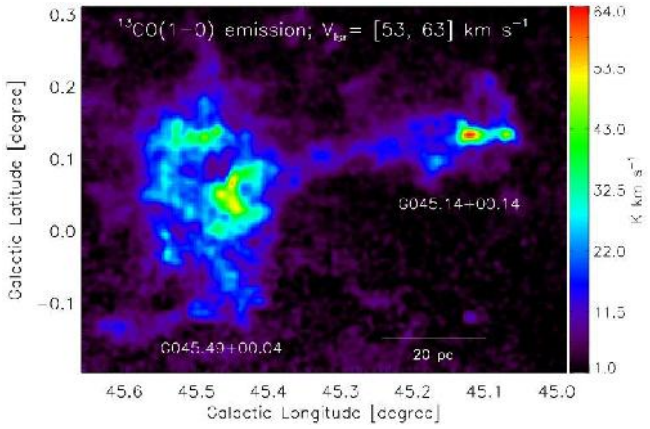

Figure 13: The panel shows the FUGIN ^{13}CO(1-0) moment-0 map of an area hosting the sites, G045.49+00.04 and G045.14+00.14.

These sites were primarily identified and catalogued as extended clouds with the prefix name of Galactic Ring Survey Molecular Cloud. We study multi-wavelength and multi-scale data to investigate the kinematics of molecular gas associated with the star-forming complexes G045.49+00.04 and G045.14+00.14 in the Aquila constellation. An analysis of the FUGIN ^{13}CO(1–0) line data unveils the presence of a giant molecular filament (GMF G45.3+0.1; length $\sim$75 pc, mass $\sim 1.1\times10^6$ $M_\odot$) having a coherent velocity structure at [53, 63] km s^{-1}. The GMF G45.3+0.1 hosts G045.49+00.04 and G045.14+00.14 complexes at its opposite ends. We find large scale velocity oscillations along GMF G45.3+0.1, which also reveals the linear velocity gradients of -0.064 and $+0.032$ km s^{-1} pc^{-1} at its edges. The photometric analysis of point-like sources shows the clustering of young stellar object candidate sources at the filament's edges where the presence of dense gas and HII regions are also spatially observed. The Herschel continuum maps along with the CHIMPS ^{13}CO(3–2) line data unravel the presence of parsec scale hub-filament systems in both the sites G045.49+00.04 and G045.14+00.14. Our study suggests that the global collapse of GMF G45.3+0.1 is end-dominated, with addition to the signature of global non isotropic collapse at the edges. Overall, GMF G45.3+0.1 is the first observational sample of filament where the edge collapse and the hub-filament configurations are simultaneously investigated. These observations open up the new possibility of massive star formation, including the formation of hub-filament systems.

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This work was done in collaboration with D. K. Ojha (Department of Astronomy and Astrophysics, Tata Institute of Fundamental Research, India), L. E. Pirogov (Institute of Applied Physics of the Russian Academy of Sciences, Russia.

(N. K. Bhadari, L. K. Dewangan and A. K. Maity)

Unraveling the observational signatures of cloud-cloud collision and hub-filament systems in W31

Massive OB stars ($>$ 8 $M_\odot$) have a great impact on the galaxy structure, evolution, and next-generation star formation.

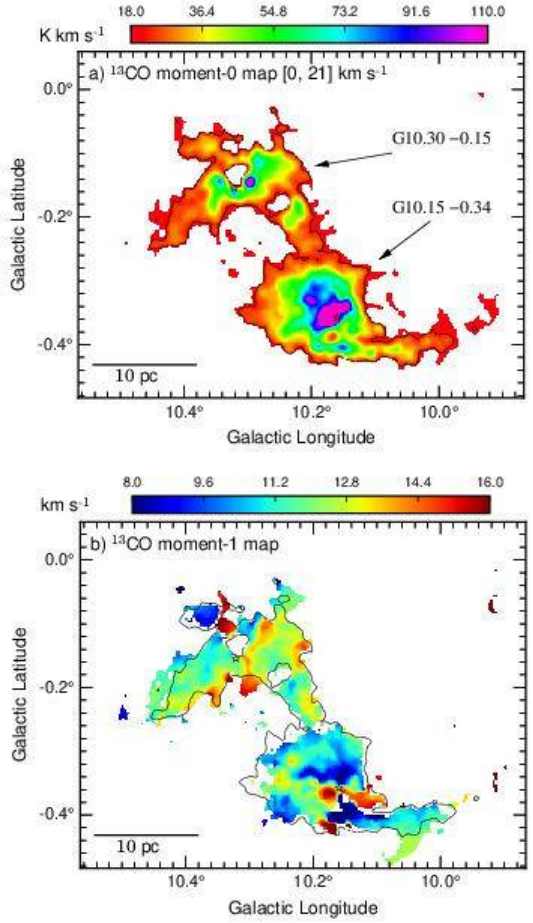

Figure 14: a) The panel displays the SEDIGISM ^{13}CO(J = 2–1) moment-0 map at [0, 21] km s^{-1} toward the W31 complex hosting the sites G10.30-0.15 and G10.15-0.34. b) The SEDIGISM moment-1 map of the ^{13}CO emission toward the W31 complex. The ^{13}CO emission contour at 22 K km s^{-1} is also shown in each panel.

However, the formation of such stars is not fully understood. The study of the formation of massive OB stars is related to the understanding of the mass accumulation processes from the surroundings. To understand the formation process of massive stars, we carried out a multi-scale and multi-wavelength study of the W31 complex hosting two extended H ii regions (i.e., G10.30-0.15 and G10.15-0.34) powered by a cluster of O-type stars. Several Class I protostars and a total of 49 ATLASGAL 870 μm dust clumps (at d $\sim$3.55 kpc) are found toward the H ii regions where some of the clumps are associated with the molecular outflow activity. These results confirm the existence of a single physical system hosting the early phases of star formation (see Figure 14a). The Herschel 250 μm continuum map shows the presence of a hub-filament system toward both G10.30-0.15 and G10.15-0.34. The central hubs harbor H ii regions and they are depicted with extended structures (with T_d $\sim$25-32 K) in the Herschel temperature map. In the direction of G10.15-0.34, an analysis of the NANTEN2 ^{12}CO(J = 1-0) and SEDIGISM ^{12}CO(J = 2-1) line data supports the presence of two cloud components around 8 and 16 km s^{-1}, and their connection in velocity space. A spatial complementary distribution between the two cloud components is also investigated toward G10.15-0.34, where the signposts of star formation, including massive O-type stars, are concentrated. These findings favor the applicability of cloud-cloud collision around 2 Myr ago in G10.15-0.34. Overall, our observational findings support the theoretical scenario of cloud-cloud collision in W31 (see Figures 14a and 14b), which explains the formation of massive stars and the existence of hub-filament systems.

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This work was done in collaboration with H. Sano (National Astronomical Observatory of Japan, Mitaka, Japan), K. Tachihara and Y. Fukui (Department of Physics, Nagoya University, Japan).

(A. K. Maity, L. K. Dewangan and N. K. Bhadari)

Tracers of Dense Gas in the Outer Galaxy

We have mapped HCN and HCO$^+$ line emission toward a sample of seven star-forming regions (with $12+\log[\mathrm{O/H}]$ range from 8.34 to 8.69) in the outer Milky Way (Galactocentric distance > 9.5 kpc), using the 14-meter radio telescope of the Taeduk Radio Astronomy Observatory (TRAO). We compare these two molecular lines with other conventional tracers of dense gas, millimeter-wave continuum emission from dust and extinction thresholds ($\mathrm{A_V} > 8$ mag), inferred from the ^{13}CO line data. HCN and HCO$^+$ correlate better with the millimeter emission than with the extinction criterion. A significant amount of luminosity comes from regions below the extinction criterion and outside the millimeter clump for all the clouds. The average fraction of HCN luminosity from within the regions with $\mathrm{A_V} > 8$ mag is 0.343 ± 0.225; for the regions of millimeter emission, it is 0.478 ± 0.149. Based on a comparison with column density maps from Herschel, HCN and HCO$^+$ trace dense gas in high column density regions better than does ^{13}CO. HCO$^+$ is less concentrated than HCN for outer Galaxy targets, in contrast with the inner Galaxy sample, suggesting that metallicity may affect the interpretation of tracers of dense gas. The conversion factor between the dense gas mass and line luminosities of HCN and HCO$^+$, when integrated over the whole cloud, is comparable with factors used in extragalactic studies.

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This work has been done in collaboration with Sudeshna Patra, (IISER Tirupati), Neal J. Evans (The University of Texas, USA; KASI), Kee-Tae Kim (KASI, UST, Republic of Korea).

(Manash Samal)

Probing the global dust properties and cluster formation potential of the giant molecular cloud G148.24+00.41

Clouds more massive than about 10^5 M$_\odot$ are potential sites of massive cluster formation. Studying the properties of such clouds in the early stages of their evolution offers an opportunity to test various cluster formation processes. We make use of CO, Herschel, and UKIDSS observations to study one such cloud, G148.24+00.41.

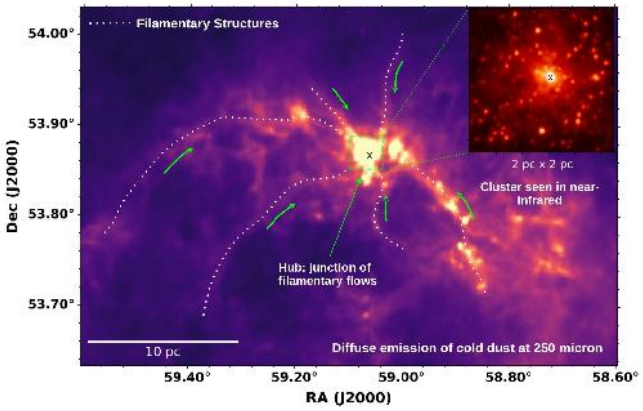

Figure 15: *Herschel* 250 μm image of cloud, revealing the filamentary structures in its central area. The inset image shows the zoomed-in view of the central region in *Spitzer* 3.6 μm, which is taken from GLIMPSE360 survey. It shows the presence of an embedded cluster in the hub. The cross sign shows the position of the massive YSO.

Our results show the cloud to be of high mass ($\sim 1.1 \times 10^5$ M$_\odot$), low dust temperature ($\sim$ 14.5 K), nearly circular (projected radius $\sim$ 26 pc), and gravitationally bound with a dense gas fraction of $\sim$ 18% and a density profile with a power-law index of ~ -1.5. Comparing its properties with those of nearby molecular clouds, we find that G148.24+00.41 is comparable to the Orion-A molecular cloud in terms of mass, size, and dense gas fraction. From our analyses, we find that the central area of the cloud is actively forming protostars and is moderately fractal with a Q-value of $\sim$ 0.66. We also find evidence of global mass-segregation in the cloud, with a degree of mass-segregation (Λ_{MSR}) ≈ 3.2. We discuss these results along with the structure (Figure 15) and compactness of the cloud, the spatial and temporal distribution of embedded stellar population, and their correlation with the cold dust distribution, in the context of high-mass cluster formation. Comparing our results with models of star cluster formation, we conclude that the cloud has the potential to form a cluster in the mass range $\sim$ 2000–3000 M$_\odot$ through dynamical hierarchical collapse and assembly of both gas and stars.

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This work has been done in collaboration with D. L. Walker (JBCA, The University of Manchester, UK), A. Zavagno (LAM, France).

(Vineet Rawat and Manash Samal)

Investigating stellar variability in the open cluster region NGC 381

Open clusters are known to host a rich variety of variable stars. These stars play a crucial role in our understanding of intrinsic properties such as pulsation, rotation, and emission as well extrinsic properties of stars such as geometrical effects in the case of eclipsing binaries. The study and characterization of the variability in open cluster NGC 381 has been done in accordance with the above necessity. The cluster NGC 381 region is extensively observed in V and I bands for 27 nights from 2017 October 1 to 2019 January 14. We found a rich variety of variable stars in the cluster. We identified a total of 10 eclipsing binaries (Figure 16) out of which 2 are Algol type (EA) while 8 are W UMa type (EW) binaries. The estimated ages of these EW binaries are greater than 0.6 Gyr which is in agreement with the formation time constraint of $\geqslant$ 0.6 Gyr on short-period eclipsing binaries. The estimation of the physical parameters of the three EW type binaries is done using PHOEBE model-fitting software. The pulsating variable stars include one each from δ Scuti and γ Dor variability class. We determined the pulsation modes of pulsating variables with the help of the FAMIAS package. We obtained 15 rotational variables stars comprising four dwarf stars identified on the basis log(g) versus log(T_{eff}) diagram. These dwarf stars are found to have generally larger periods than the remaining rotational variables.

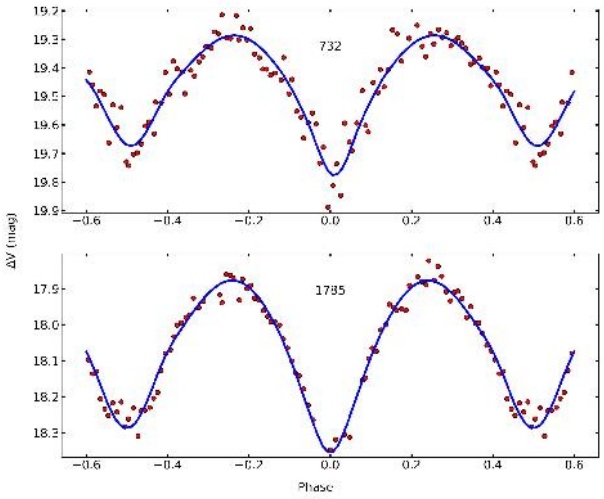

Figure 16: The light curves of the two W UMa type eclipsing binary systems whose physical parameters are estimated using PHOEBE code model fittings. The blue continuous curves show the best model fits of the PHOEBE model fitting code. The ID for each binary system is given at the top of each subplot.

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This work has been done in collaboration with Y. C. Joshi, A. Panchal (ARIES, Nainital, India) and A. S. Gour (Ravishankar Shukla University, Raipur, India.

(Jayanand Maurya)

Optical Linear Polarisation Study toward Czernik 3 Open Cluster at Different Spatial Scales

Dust is an important component of our Galaxy, accounting for only 1% of the interstellar medium but still significant. It is most evident in galactic discs, producing equatorial lanes in edge-on spirals. In other words, Within the disk, most of the material is confined to the spiral arms. Hence, dust is an excellent tracer to map the disk and, specifically, the spiral arms of the Galaxy. Studying the dust distribution in the Galaxy at longer wavelengths may cause discrepancies due to distance ambiguity caused by unknown Galactic potential. So, instead of direct tracing dust distribution in longer wavelengths, researchers try to map the structure using the indirect properties of dust, like extinction and polarisation. The extinction maps produced till date are based on some model assumptions. However, polarisation can give a direct observational signature of the dust distribution along the line of sight. With the aim to determine the number of foreground dust layers along the line of sight, we carried out the polarisation observation of a distant open cluster ($\sim$ 4.4 kpc); Czernik 3, present in the 2nd Galactic quadrant. The observations were performed using EMPOL, an EMCCD-based polarimeter on a 1.2 m telescope of Mount Abu Observatory, PRL. We observed 43 stars towards the core of the cluster in Sloan i-band, on the nights of 13 January and 7 February 2021 and reduced the data using self-scripted automated Python routines.

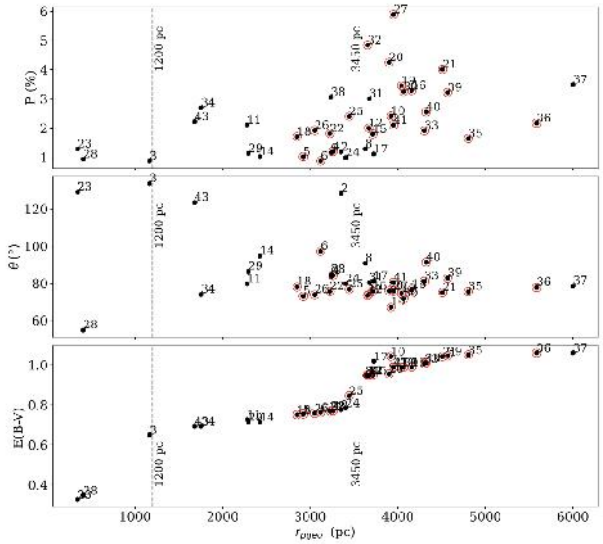

Figure 17: Variation of degree of polarization (upper panel), polarization angle (middle panel), and extinction (lower panel) as a function of distance. Probable (P $>$ 0.9) member stars of the cluster are marker by red open circles.

The observational results of Czernik 3 show a large range in the degree of polarisation ($2.42\% \pm 1.18\%$), indicating that the dust is not uniformly distributed over the plane of the sky. Combining the distance information from Gaia data with the observed polarisation, we see at least two jumps in the degree of polarisation, polarisation angle and extinction as a function of distance, as shown in Figure 17. These jumps indicate at least two foreground dust clouds (1200 pc and 3450 pc) crossing the line of sight; one is coinciding with the LDN 1306 Lynds cloud, and the other is present closer to the cluster. The distance of the foreground clouds is further confirmed with the molecular CO data and HI data. The large-scale dust distribution was also investigated in the study, using the polarisation information of nearby clusters within 15° of Czernik 3. The variation of the degree of polarisation in such a large region indicates low dust contents and decreased stellar density in the 1-2 kpc region towards the line of

sight. We conclude that the 1-2 kpc region is related to the inter-arm region between the Local and Perseus Arm. In addition to the dust distribution, we also redefined the membership of the Czernik 3 cluster using more accurate astrometric Gaia EDR3 data and compared it with the photometric and polarimetric membership assignment. Using the member stars in the core region, the distance to Czernik 3 is constrained to 3.6 ± 0.8 kpc.

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This work was done in collaboration with Devendra Bisht (Key Laboratory for Research in Galaxies and Cosmology, University of Science and Technology of China, Chinese Academy of Sciences, Hefei, Anhui, Peoples Republic of China.

(N. Uppal and S. Ganesh)

Swift and XMMNewton observations of an RS CVn-type eclipsing binary SZ Psc: superflare and coronal properties

Current understanding of the mechanisms of stellar flares is developed based on the Sun. Stellar flares generally occur close to the active regions. Coronal plasma near the active regions confines in closed magnetic structure called loop. The loops have a localized magnetic field of the order of a few kilo-Gauss and extend from the lower atmosphere of these active regions to coronal heights. The chromospheric foot points of these loops are jostled by convective motions, whereas the loops get twisted and distorted depending on the local conditions until they undergo a magnetic reconnection process near the loop tops. The reconnection process results in a rapid and transient release of magnetic energy in the stellar corona, and the event is termed a flare. Flares produced by the RS Canum Venaticorum (RS CVn) type binaries show many analogies with the solar flares. These binaries are close but detached systems, typically consisting of a G-K giant/subgiant and a late-type main-sequence/subgiant companion. Based on the rotation period (P), the RS CVn binaries are subdivided into three following categories: short-period (P $\leq$ 1 d), classical (1 d $\leq$ P $<$ 14 d), and long-period (P $\geq$ 14 d) binaries. The tidal forces between the components of the RS CVn binaries can cause the rotational period to be synchronized with the orbital period. Moreover, a thicker convection zone of the evolved giant/subgiant component leads to a much higher level of magnetic activities in RS CVn binaries than in the Sun and other late-type stars. Analysis of flares in cool giants and subgiants is therefore very important as it gives us an opportunity to probe the structure and dynamic behavior of the corona of RS CVn binaries, which in principle can be significantly different from the corona of dwarf stars.

An in-depth study of a large and long duration ($>$1.3 d) X-ray flare, observed on an RS CVn-type eclipsing binary system SZ Psc was carried out by using observations from Swift observatory. In the 0.35-10 keV energy band, the peak luminosity is estimated to be 4.2×10^{33} erg/s. The quiescent corona of SZ Psc was observed about 5.67 days after the flare using Swift observatory, and also about 1.4 yr after the flare using the XMM-Newton satellite. The quiescent corona is found to consist of three temperature plasma: 4, 13, and 48 Million Kelvin. High-resolution X-ray spectral analysis of the quiescent corona of SZ Psc suggests that the high first ionization potential (FIP) elements are more abundant than the low-FIP elements. The time-resolved X-ray spectroscopy of the flare shows a significant variation in the flare temperature" emission measure, and abundance. Using the hydrodynamic loop modeling, we derive the loop length of the flare as 6.3×10^{11} cm, whereas the loop pressure and density at the flare peak are derived to be 3.5×10^{3} dyn cm^{-2} and 8×10^{10} cm^{-3}, respectively. The total magnetic field to produce the flare ii s estimated to be 490 G. The large magnetic field at the coronal height is supposed to be due to the presence of an extended convection zone of the subgiant and the high orbital velocity.

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This work was done in collaboration with J. C. Pandey of ARIES, Nainital and I. S. Savanov of Institute of Astronomy, Russian Academy of Sciences, Russia.

(Subhajit Karmakar and Sachindra Naik)

Optical and X-ray studies of Be/X-ray binary 1A 0535+262//HD 245770 during its 2020 giant outburst

X-ray binaries are one of the brightest X-ray sources in our galaxy. They consist of a compact object (black hole, neutron star, or white dwarf) emitting in X-rays and a companion star which is in the process of evolution. In the Be/X-ray binaries (BeXRBs), the optical companion is an Oe/Be star that shows emission lines in the optical/infrared spectrum and infrared excess, unlike classical stars that show absorption lines and no infrared excess. The unique properties of Be stars are ascribed to the equatorial circumstellar disc around them. In BeXRBs, the compact object, a neutron star, emits X-rays by accreting matter from the decretion disc. These systems show two types of X-ray outbursts: normal ($L_X < 10^{37}$ ergs s^{-1}) and giant ($L_X > 10^{37}$ ergs s^{-1}). The normal outbursts are attributed to the periastron passage of the neutron star. However, the giant outbursts are unpredictable. To understand the mass accretion mechanism during a giant outburst, we studied a BeXRB 1A 0535+262/HD245770 that went onto a giant X-ray outburst in October 2020. The peak X-ray flux of the outburst was recorded to be $\sim$11 Crab in the 15-50 keV range, the highest ever observed from the pulsar. We performed optical observations with the MFOSC-P instrument mounted on the 1.2 m telescope at Mount Abu Infrared Observatory in the 6000-7200 Å band before, during, and after the outburst to investigate the evolution of the circumstellar disc of the Be star between 2020 February and 2022 February. We also used long-term photometry data from the American Association of Variable Star Observers (AAVSO) database.

Our optical spectra exhibit prominent emission lines at 6563 Å (HI), 6678 Å (HeI), and 7065 Å (HeI). We found a significantly variable Hα line in the spectra. The single-peaked line profile appeared asymmetric with broad red- and blue-wings in the data before and during the giant X-ray outburst. The post-outburst observations, however, resulted in a double-peaked profile with asymmetry in the blue-wing (Figure 18). Our observations before the outburst confirmed a larger Be disc that decreased in size as the outburst progressed. Furthermore, the observed variabilities in the Hα line profile and parameters suggest the presence of a highly misaligned, precessing, and warped Be disc. The torque applied by the neutron star on the disc during the periastron passage, causes the disc to precess. As the disc is not a solid object, rings of matter in the disc precess at

different rates, causing the warping of the disc. The neutron star can accrete sufficient amount of matter required for a giant outburst when the warped region aligns in the path of the neutron star. Therefore, the presence of a warped circumstellar disc around the Be star is the most probable cause of a giant X-ray outburst in the Be/X-ray binaries. Using AstroSat observation of the pulsar 1A 0535+262 during its October 2020 giant outburst, we detected X-ray pulsations at $\sim$103.55 s in the light curve up to 110 keV. We found strongly energy-dependent pulse profiles with increasing contribution of the pulsing component in hard X-rays. The broad-band spectral fitting in the 0.7-90.0 keV range confirmed the presence of the known cyclotron resonance scattering feature at 46.3 keV, suggesting the magnetic field of the neutron star to be 5.2×10^{12} G.

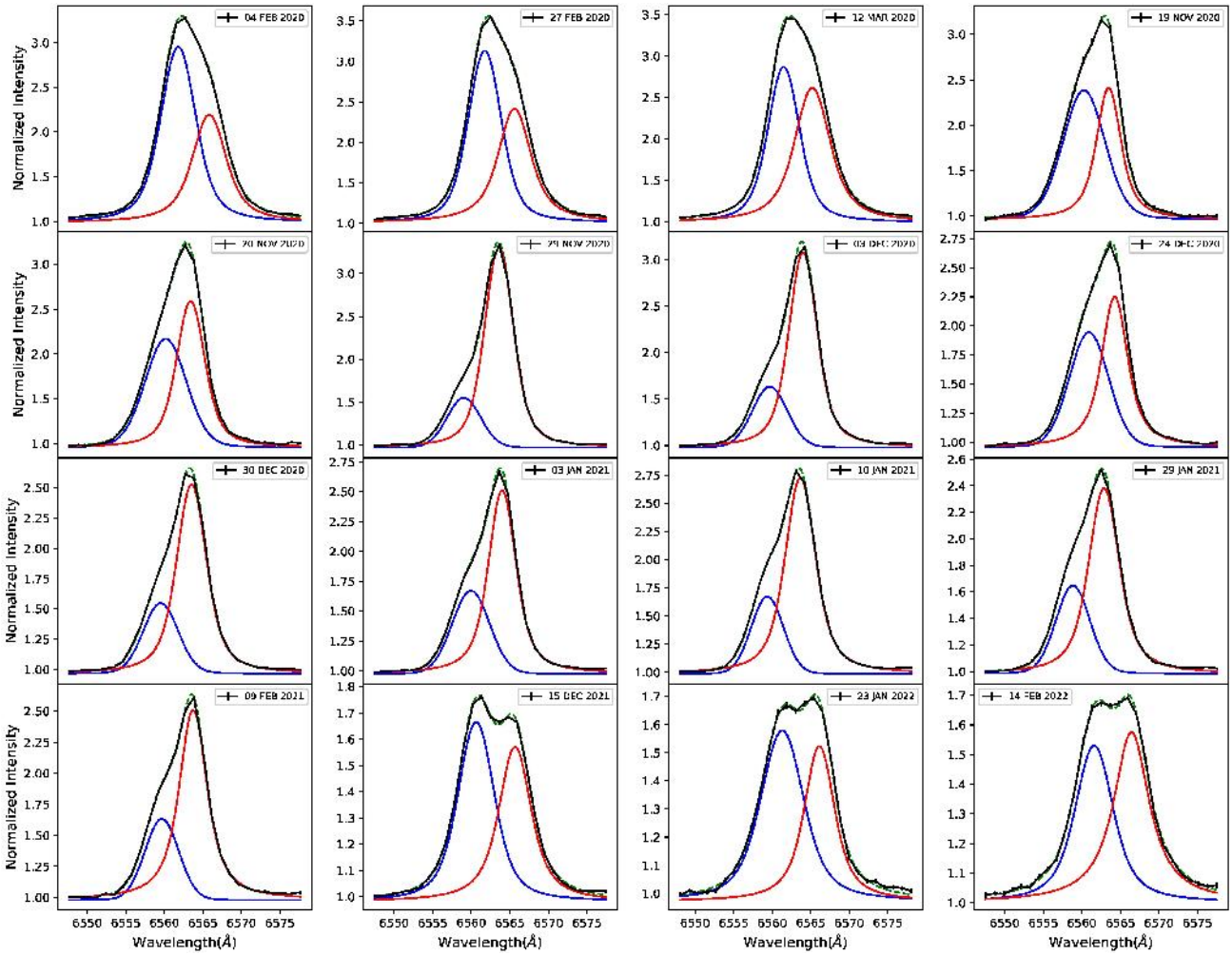

Figure 18: The Hα line profiles (solid black line) of 1A 0535+262/HD245770 during our observations and corresponding best-fitted Voigt functions (dashed green line). The observation dates are quoted on the right of the corresponding profiles. The red and blue color profiles correspond to the red and blue shifted components of the Hα line, respectively.

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This work was done in collaboration with Gaurava K. Jaisawal of National Space Institute, Denmark and Arghajit Jana of Institute of Astronomy, National Tsing Hua University, Hsinchu, Taiwan.

(Birendra Chhotaray, Neeraj Kumari, Sachindra Naik and Vipin Kumar)

Detection of a massive Galactic black hole in MAXI J1631–479 using X-ray spectroscopy

The X-ray binary MAXI J1631–479 went into outburst for the first time during the winter of 2018 and was observed with most modern observatories. We attempted to constrain the black hole's mass, spin, disk inclination along with other properties of the accretion disk using NuSTAR observations. The traditional and robust way of measuring mass is by calculating the binary mass function from the radial velocity measurement of the secondary star. Black hole mass can also be measured from the thermal X-ray flux that is emitted from the inner accretion disk when its inner edge remains at the inner-most stable circular orbit. The rationale is that this flux is a function of the black hole mass, along with other parameters such as spin of the black hole, inclination of the inner disk and distance to the source. This dependence on so many parameters makes

this method prone to error. Therefore, we undertook utmost care to ensure that all the important parameters of the system are well constrained. The spin and inclination were constrained with reflection spectroscopy of the NuSTAR spectra. The spin was found to be high with $a > 0.996$ and the inclination of the inner disk was constrained between 50° - 70°. Since no independent distance measurement was available for the source, we carried out a Monte Carlo simulation to constrain the distance using optical flux reported during the outburst. In the simulation we iterated over a wide range of parameters for distance, spin, inclination, and inner-disk temperature and calculated the expected optical flux. Considering a possible ambiguity in the optical counterpart of the source, a series of acceptable distances were selected (see gray histogram in Figure 19). A 99% lower limit on the distance was found to be 4.5 kpc. With firm limits on the spin and inclination we fitted a set of 9 soft state NICER spectra simultaneously for black hole mass. With the limit on distance obtained from our simulation the lower limit on mass falls in a range of 15 - 45 $M_\odot$. The bottom panel of Figure 19 shows the reduced χ^2 of the NICER fits which clearly suggests that the low spin - low inclination combination (that gives the lower limit on mass) gives a worse fit compared to the high spin - high inclination combination. Therefore, the mass of the black hole is likely to be much higher. The high mass estimate also becomes evident when compared with another source (4U 1630–47, see the green lines in Figure 19) using the same technique. If true MAXI J1631–479 will contain the most massive black hole hosted in X-ray binaries in our galaxy known to date.

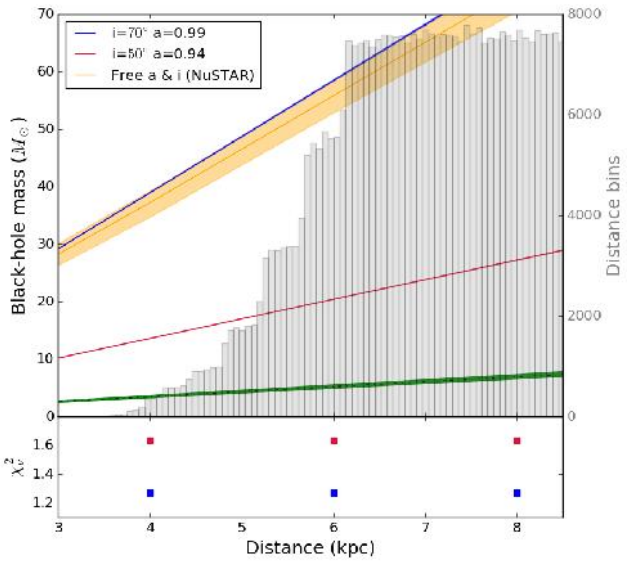

Figure 19: Top panel: The red and blue lines represent the black hole mass - distance relation obtained by simultaneously fitting nine soft state *NICER* spectra for low spin - low inclination and high spin - high inclination combinations respectively. The orange line represents the same relation for fits with *NuSTAR* spectra with spin and inclination kept free while fitting. The gray histogram represents the likelihood of distance to the source obtained by comparing the observed optical flux to that expected from an irradiated disk. The green line at the bottom is for another black hole binary 4U 1630–47 with $a = 0.90$ and $i = 65^\circ$, obtained by fitting four soft state Swift/XRT spectra. The shaded region along the lines represent 1-σ statistical uncertainty on the mass for all except the *NuSTAR* fits where the error is 90%. Bottom panel: The χ^2_ν values from the simultaneous *NICER* fits for the two combinations of spin and inclination and for different distances.

The confirmation of a massive black hole in an X-ray binary has a couple of consequences. Firstly, it raises questions on stellar evolution theories which fail to explain massive black holes from stellar collapse. Baverra et al. (2022) try to explain the formation of massive black holes through merger scenarios. Moreover, the absence of more such sources has been ascribed to a selection bias (Jonker et al. 2021). Such a massive black hole falls in a range where binary black holes are detected during mergers using gravitational waves. This puts to rest many theories which attempt to explain an, hitherto, apparent dichotomy in measured masses from gravitational waves and electromagnetic waves. The mass distribution is likely to be more continuous than previously thought.

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This work is done in collaboration with J. Garcia, R. Connors (Cahill Center for Astronomy and Astrophysics, California Institute of Technology, USA).

(S. K. Rout and S. V. Vadawale)

AstroSat Observation of X-ray Dips and State Transition in the Black Hole Candidate MAXI J1803-298

An X-ray binary (XRB) can be termed as a transient or a persistent source, depending on its X-ray activity. A transient source spends most of the time in quiescence phase with X-ray luminosity, $L_X < 10^{32}$ erg s^{-1} and show occasional outbursts when the X-ray intensity rises by about three orders of magnitude or more compared to the quiescence phase. Instead, a persistent source is always active in X-rays with X-ray luminosity, $L_X > 10^{35}$ erg s^{-1}. Recently, MAXI/GSC discovered a new X-ray transient MAXI J1803-298 when the source showed an X-ray outburst on 2021 May 1. The source was subsequently observed with several other X-ray missions. We present the results obtained from broad-band X-ray timing and spectral analysis of MAXI J1803-298 using an AstroSat observation on 2021 May 11-12. Four periodic absorption dips with a periodicity of 7.02 hours are detected in the light curve. AstroSat observe the source when it was undergoing a transition from the hard-intermediate state to the soft-intermediate state. Our timing analysis reveals the presence of a sharp Type-C quasi-periodic oscillation (QPO) in the power-density spectra with an evolving QPO frequency ranging from 5.31$\pm$0.02 to 7.61$\pm$0.09 Hz. We investigate the energy dependence of the QPO and do not find this feature in the PDS above 30 keV. The combined 0.7-80 keV SXT and LAXPC spectra are fitted with a model consisting of thermal multi-colour blackbody emission and Comptonized emission components. We perform time-resolved spectroscopy by extracting spectra during the dip and non-dip phases of the observation. A neutral absorber is detected during the dip and non-dip phases though a signature of an ionized absorber is also present in the dip phases. The spectral and temporal parameters are found to evolve during our observation. We estimate the mass function of the system as f(M) = 2.1-7.2 solar mass and the mass of the BH candidate in the range of M_{BH} $\sim$3.5-12.5 solar mass. This confirms the X-ray source as a black hole.

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This work was done in collaboration with Gaurava K. Jaisawal of National Space Institute, Denmark and Shivangi Gupta of Universidad Metropolitana de Ciencias de la Educacion, Chile.

(Arghajit Jana, Sachindra Naik, Birendra Chhotaray and Neeraj Kumari)

Evidence of heavy obscuration in the low-luminosity AGN NGC 4941

Active galactic nuclei (AGNs) are believed to be powered by accretion onto the supermassive black holes that reside at the center of the galaxies. The UV/optical seed photons from the accretion disk undergo inverse Comptonization in the corona producing emission in X-rays. A fraction of the emitted X-ray photons is reflected in the surrounding materials, producing Fe K-line complex in 6–8 keV range and a reflection hump in 15–40 keV range. Additionally, an excess in the soft X-ray ($<$1 keV), known as soft-excess, is also observed. Based on the optical observations, the AGNs are broadly classified into two classes depending on the presence or absence of broad emission lines. The broad emission lines are observed in type-1 AGNs, while it is absent in the type-2 AGNs. The unified model of AGNs explains different classes of AGNs based on the orientation of viewing angle. In this model, a dusty torus surrounds the nuclear region at a parsec scale. The type-1 AGNs are observed face-on where the BLRs are visible, while the type-2 AGNs are viewed edge-on where the torus obscures the BLR. Additionally, the narrow emission lines (originate in narrow line emitting regions or NLRs) are observed in both types of AGNs.

Recently, a new sub-class of AGNs has emerged, known as changing-look AGNs. In optical changing-look events, the type-1 (or type 1.2/1.5) AGNs transit to type2 (or type 1.8/1.9) and vice versa with the disappearance or appearance of the broad emission lines. Several nearby galaxies, such as NGC 1566, NGC 3516, Mrk 590, NGC 2617, Mrk 1018 have been found to show such peculiar behavior. A different type of changing-look events have been observed in the X-ray wavebands, with an AGN switching between Compton-thin ($N_H < 10^{24}$ cm^{-2}) and Compton-thick (CT; $N_H > 10^{24}$ cm^{-2}) states. The X-ray CL events have been observed in many AGNs, namely IC 751, NGC 4507, NGC 6300. Low luminosity AGNs (LLAGNs; bolometric luminosity $L_{bol} < 10^{43}$ erg s^{-1}) holds key to understand the changing-state events. Recently, NGC 1566 showed an outburst in June 2018 after remaining in the low luminosity state for over a decade. During the outburst, the optical, UV, and X-ray flux increased by 25–30 times compared to the low luminosity state with the reappearance of broad emission lines. Similar behavior is also observed in NGC 3516.

Thus, it is essential to study the accretion properties of low-luminosity AGNs. NGC 4941 is classified as a Seyfert 2 galaxy with a morphological class of Sa. The ASCA, BeppoSAX, Suzaku and NuSTAR observations revealed a heavily obscured nucleus with line of sight column density $N_H > 10^{23}$ cm^{-2} and a strong Fe K$_\alpha$ emission line in the spectrum. The mass of the black hole in NGC 4941 is reported to be $10^{6:9}$ solar mass. We performed spectral and timing studies of NGC 4941 in broad energy range using data from NuSTAR (on 19 January 2016) and Swift/BAT observations. We find similar variability in 3-10 keV and 10-60 keV energy ranges with fractional rms variability of $\sim$14%. We investigate broad-band spectral properties of the source in 3-150 keV range, using data from NuSTAR and Swift/BAT, with phenomenological slab model and physically motivated MYTORUS model. From the spectral analysis, we find heavy obscuration with global average column density of the obscured material as 3.09×10^{24} cm^{-2}. Evidence of a strong reflection component is observed in the spectrum. We detect a strong iron line with equivalent width of $\sim$1 keV. From the slab model, we obtain the exponential cutoff energy as 177 keV. From this, we estimate the Compton cloud properties with the hot electron temperature kT_e = 59 keV and the optical depth τ = 2.7.

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(Arghajit Jana, Sachindra Naik and Neeraj Kumari)

Absorption Variability of the Highly Obscured Active Galactic Nucleus NGC 4507

Over the years, many AGNs are observed to show variable absorption column density (N_H) in a time-scale of hours to years. The short-term variations (on time-scales of days) are believed to be associated with the broad-line emitting region (BLR), while the long-term variability (on time-scales of months to years) are believed to be caused by the clumpy molecular torus. A growing number of AGNs, e.g. UGC 4203, NGC 4151, NGC 2992, IC 751, NGC 6300, have shown variable N_H by repeated X-ray observation. In recent years, a new sub-class of AGNs, known as changing-look AGN has emerged. In these objects, the line of sight column density can go from a Compton-thin ($N_H < 10^{24}$ cm^{-2}) to a Compton-thick state (CT; $N_H > 10^{24}$ cm^{-2}) level, or vice versa. These events can lead to a dramatic change in the observed X-ray spectrum, which can go from being reflection dominated (in the Compton-thick state) to transmission dominated (in the Compton-thin state), or vice versa. These events are believed to be an important confirmation of the clumpiness of the BLR or torus.

NGC 4507 is a nearby (z = 0.0118) barred spiral galaxy, classified as SAB(s)ab. NGC 4507 is reported to be one of the brightest (F_{obs} $\sim10^{-11}$ erg cm^{-2} s^{-1} in 2-10 keV range) Seyfert 2 galaxies in the hard X-ray band. Over the years, several X-ray studies have revealed a variable N_H in the range of $\sim$1–9$\times10^{23}$ cm^{-2} based on the observations by Ginga, ASCA, BeppoSAX, XMMNewton, and Chandra. We present here a detailed study of the highly obscured active galaxy NGC 4507, performed using four NuSTAR observations carried out between May and August in 2015 (130 ks in total). Using various phenomenological and physically motivated torus models, we explore the properties of the X-ray source and those of the obscuring material. The primary X-ray emission is found to be non-variable, indicating a stable accretion during the period of the observations. We find the equatorial column density of the obscuring materials to be $\sim2\times10^{24}$cm^{-2}while the line-of-sight column density to be $\sim$7–8 $\times$ 10^{23}cm^{-2}. The source is found to be deeply buried with the torus covering factor of $\sim$0.85. We observe variability in the line-of-sight column density on a time-scale of $<$35 d. The covering factor of the Compton-Thick material is found to be $\sim$0.35 in agreement with the results of recent X-ray surveys. From the variability of the line-of-sight column density, we estimate that the variable absorbing material is likely located either in the BLR or in the torus.

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This work was done in collaboration with C. Ricci of Universidad Diego Portales, Santiago, Chile, A. Tanimoto of The University of Tokyo, Japan.

(Arghajit Jana, Sachindra Naik, Neeraj Kumari and Prantik Nandi)

Broadband X-ray Spectroscopy and Estimation of Spin of the Galactic Black Hole Candidate GRS 1758-258

Black holes (BH) in X-ray binaries are powered by the accretion process, where matter from the companion star gets accreted onto the central black hole. The gravitational energy of the accreted matter is converted to radiation which is emitted as electromagnetic spectrum. A BH is characterized by its mass (MBH) and spin (a*). Estimation of the BH spin is harder compared to the estimation of mass. There exist various direct methods to estimate the BH mass, such as radial velocity measurement of the secondary, dips, and eclipses in the light curves. The BH mass can also be estimated from the spectral modeling and timing analysis. The BH spin can be estimated in two processes: the continuum fitting (CF) method and the study of Fe line and reflection spectroscopy. Both the methods require measuring the inner edge of the accretion disk that extends up to the inner most stable circular orbit (ISCO).

GRS 1758-258 is a BH X-ray binary located in the close vicinity of the Galactic center. It is one of the few persistent BHXRBs in our Galaxy. The central object in the binary is considered to be a BH based on its spectral and timing properties. GRS 1758-258 also shows two extended radio lobes, which make the system a microquasar. For a long time, the companion star was not identified due to the dense stellar population in the field. Spectroscopic study suggested that the companion is likely to be an A-type main-sequence star. We present here the results of a broadband (0.5-78 keV) X-ray spectral study of the persistent Galactic black hole X-ray binary GRS 1758-258 observed simultaneously by Swift and NuSTAR. Fitting with an absorbed power-law model revealed a broad Fe line and reflection hump in the spectrum. We used different flavors of the relativistic reflection model for the spectral analysis. All models indicate the spin of the black hole in GRS 1758-258 is $>$0.92. The source was in the low hard state during the observation, with the hot electron temperature of the corona estimated to be kT_e $\sim$140 keV. The black hole is found to be accreting at $\sim$1.5% of the Eddington limit during the observation, assuming the black hole mass of 10 solar mass and distance of 8 kpc.

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This work was done in collaboration with A. Jana and H. K. Chang of Institute of Astronomy, National Tsing Hua University, Taiwan, and A. Chatterjee and S. Safi-Harb of University of Manitoba, Canada.

(Sachindra Naik)

Search and Characterization of Remnant Radio Galaxies in the XMM-LSS Deep Field

The remnant phase of a radio galaxy is characterized by the cessation of active galactic nuclei activity, resulting in the jets ceasing to feed plasma to the radio lobes. In this paper, we present a search for and the characterization of remnant candidates in a 12.5 deg^2 area of the XMM-Newton Large-Scale Structure field, using deep radio observations at 325 MHz from the Giant Meterwave Radio Telescope (GMRT), at 150 MHz from the LOw Frequency ARray (LOFAR), at 1.4 GHz from the Jansky Very Large Array (JVLA), and at 3 GHz from the VLA Sky Survey (VLASS). By using both morphological criteria (undetected radio core) as well as spectral criteria (high spectral curvature and ultra-steep spectrum), we identify 21 remnant candidates that are found to reside mostly in non-cluster environments, and exhibit diverse properties in terms of morphology, spectral index ($\alpha^{1400\ \mathrm{MHz}}_{150\ \mathrm{MHz}}$ in the range of -1.71 to -0.75 with a median of -1.10), and linear radio size (ranging from 242 kpc to 1.3 Mpc with a median of 469 kpc). Figure 20 shows 325 MHz image of a remnant radio galaxy from our sample. Our study attempts to identify remnant candidates down to the flux density limit of 6.0 mJy at 325 MHz, and yields an upper limit on the remnant fraction (f_{rem}) to be around 5 per cent. The observed f_{rem} seems consistent with the predictions of an evolutionary model assuming power-law distributions of the duration of the active phase and jet kinetic power with an index of -0.8 to -1.2.

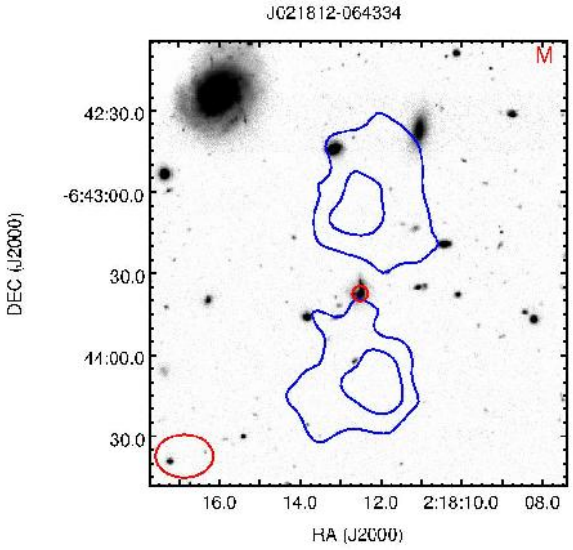

Figure 20: The image of a remnant J021218-064334 showing 325 MHz GMRT radio contours (in blue) overlaid on the corresponding i band Subaru optical image. The potential host galaxy is marked with a small circle around it. The 325 MHz GMRT synthesized beam of 10″.7 $\times$ 7″.9 is shown by an ellipse (in red) in the bottom left corner.

doi : https://doi.org/10.3847/1538-4357/acaf01

This work has been done in collaboration with Prof. Ishwara-Chandra, Prof. Yogesh Wadadekar from NCRA-TIFR Pune, India and Dr. Ian Heywood from Oxford University.

(Sushant Dutta, Veeresh Singh and Abhijit Kayal)

Characteristics of remnant radio galaxies detected in deep radio continuum observations from SKA pathfinders

The cessation of AGN activity in radio galaxies leads to a remnant phase during which jets are no longer sustained, but lobes can be detected for a period of time before they fade away due to radiative and dynamical energy losses. The time-scale of the remnant phase and AGN duty cycle are vital to understand the evolution of radio galaxies. In this study, we report new band-3 observations with the upgraded Giant Meterwave Radio Telescope (uGMRT) for five remnant radio galaxies. Our uGMRT observations reveal emission

of low-surface-brightness in all five remnants with 400 MHz surface brightness in the range of 36−201 mJy arcmin^{-2}. With band-3 uGMRT observations, we discover wing-shaped radio morphology in one of our sample sources. Using radio observations at 150 MHz, 325 MHz, 400 MHz and 1.5 GHz, we model the radio spectral energy distributions (SEDs) of our sample sources with the continuous injection-off (CI_{OFF}) model, that assumes an active phase with continuous injection followed by a remnant phase. We obtain total source ages (t_s) in the range of 20.3−41.4 Myr with t_{OFF}/t_s distributed in the range of 0.16−0.63, which in turn suggests that they belong to different evolutionary phases.We note that when compared to the remnants reported in the literature, our sample sources tend to show lower spectral ages (see Figure 21) that can be explained by the combined effects of more dominant inverse Compton losses for our sources present at the relatively higher redshifts and possible rapid expansion of lobes in their less dense environments.

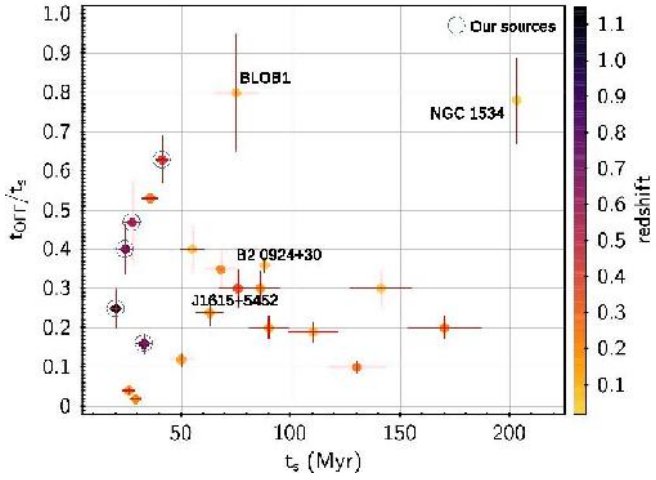

Figure 21: The plot of total source age ts versus fractional remnant time-scale (t_{OFF}/t_s). The vertical colour bar indicates the redshifts of remnant hosts. The individually studied remnant sources are marked by their popular names. Our sample sources are marked by large Blue circles.

doi : https://doi.org/10.1007/s12036-022-09883-y

This work has been done in collaboration with Prof. Ishwara-Chandra and Prof. Yogesh Wadadekar from NCRA-TIFR Pune, India.

(Sushant Dutta, Veeresh Singh and Abhijit Kayal)

Detection of radio-AGN in dust-obscured galaxies using deep uGMRT radio continuum observations

Radio observations being insensitive to the dust-obscuration, have been exploited to unveil the population of active galactic nuclei residing in galaxies with large dust content. In this work, we investigate the radio characteristics of 321 dust-obscured galaxies (DOGs; $S_{24\,\mu m}/Sr-band \geq 1000$) by using mainly deep band-3 (250−550 MHz) observations from the upgraded giant metrewave radio telescope (uGMRT) and 1.5 GHz Jansky very large array (JVLA) observations. We find that for our sample of DOGs, deep (median noise-rms = 30 μJy beam^{-1}) 400 MHz band-3 uGMRT observations yield the highest detection rate (28 per cent) among those obtained with the JVLA, and low frequency array (LOFAR) radio observations and XMM-N X-ray observations. The radio characteristics of our sample sources, i.e., linear extent (<40 kpc at z <1.2), bimodal spectral index ($\alpha_{150\,MHz}^{400\,MHz}$) distribution and the radio luminosities ($L_{1.5\,GHz} > 5.0 \times 10^{23}$ W Hz^{-1}), suggest them to be mainly consist of compact-steep-spectrum (CSS) or peaked-spectrum (PS) sources representing an early phase of the AGN-jet activity in dust-obscured environments. Figure 22 shows an example of radio detected dust-obscured galaxy which appears bright at 24 μm but very faint in the optical. With stacking, we find the existence of faint radio emission ($S_{400\,MHz}$ = 72.9 μJy beam^{-1} and $S_{1.5\,GHz}$ = 29 μJy beam^{-1} with signal-to-noise ratio of 20) in otherwise radio-undetected DOGs. Our study reveals the faint emission at a few tens of μJy level in high-z DOGs, which can be used as a test-bed for the deeper radio continuum surveys planned with the square-kilometer array (SKA) and its pathfinders.

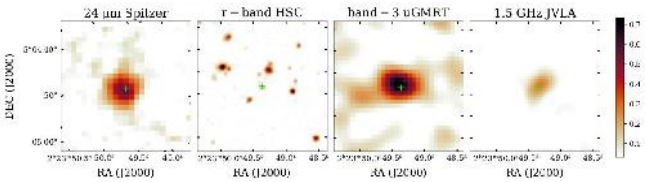

Figure 22: The 24 μm FIR, r band optical, 400 MHz uGMRT and 1.5 GHz JVLA radio images of a dust-obscured galaxy J022349-050453.

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This work has been done in collaboration with Prof. Yogesh Wadadekar and Prof. Ishwara-Chandra from NCRA-TIFR Pune, India.

(Abhijit Kayal, Veeresh Singh and Sushant Dutta)

Evidence of jet-induced optical microvariability in radio-loud narrow-line Seyfert 1 galaxies

To quantify the role of radio jets for Intra-Night Optical Variability (INOV) in radio-loud narrow-line Seyfert 1 (RLNLSy1) galaxies, we report the first systematic comparative INOV study of 23 RLNLSy1 galaxies, with 15 RLNLSy1s having confirmed detection of jets (jetted) and the remaining 8 RLNLSy1s having no detection of jets (non-jetted) based on their Very Long Baseline Array observations. We have monitored these two samples, respectively, in 37 and 16 sessions of a minimum 3-h duration each. Based upon $F\eta$-test at 99 per cent confidence level with a typical INOV amplitude (Φ) detection threshold of 3 per cent, we find the INOV duty cycles (DC) of 12 per cent for the sample of jetted RLNLSy1s, however, none of the sources showed INOV in the sample of non-jetted RLNLSy1s. Among the jetted RLNLSy1s, we find that the DC for jetted γ-ray detected (γ-ray) RLNLSy1s is found to be 34 per cent in contrast to null INOV detection in the case of non-γ-ray RLNLSy1s. It suggests that instead of the mere presence of a jet, relativistic beaming plays a significant role for INOV in the case of low-luminous high accreting AGNs, such as NLSy1s, in which dilution of the AGN's non-thermal optical emission by the (much steadier) optical emission contributed by the nuclear accretion disc is quite likely. Our study of jetted γ-ray RLNLSy1s

shows more frequent INOV detection for sources with higher apparent jet speed. Further, our results also suggest that among the NLSy1s, only jetted γ-ray RNLSy1 galaxies DC approach blazar-like DC.

doi : https://doi.org/10.1093/mnras/stac1627

IES Nainital and Prof. Hum Chand from Central University of Himachal Pradesh, Dharamshala, India.

(Vineet Ojha and Veeresh Singh)

Experimental verification of off-axis polarimetry with cadmium zinc telluride detectors of AstroSat-CZT Imager

Pixellated Cadmium Zinc Telluride (CZT) detectors capable of hard X-ray spectral measurements in $\sim$ 20 $-$ 200 keV have been used in the CZT-Imager instrument of AstroSat mission and are also planned as the primary detectors for the proposed Daksha mission aimed at discovery and characterization of electromagnetic counterparts to gravitational wave sources as well as Gamma Ray Bursts (GRBs). In addition to spectroscopy, the same CZT detectors can also be used for the measurement of X-ray polarisation using the principle of Compton scattering. This technique has been verified experimentally and was used to obtain new results for Crab pulsar with AstroSat CZTI observations. It also has been extended to carry out polarimetry of GRBs that are incident at off-axis angles; however, the polarimetric capability of off-axis sources has not been demonstrated experimentally. In this context, we carried out experiments to investigate the off-axis polarimetric capability of CZT detectors to strengthen the GRB polarimetry with AstroSat CZTI and the Daksha mission.

To investigate the off-axis polarimetric capability of CZT detectors, we developed a novel experimental setup and a source assembly for generating partially polarised X-rays. The partially polarised X-rays are collected at different off-axis configurations enabled by our experimental setup. These partially polarised X-rays may get Compton scattered in the given pixel of the CZT detector and gets absorbed in the neighboring pixel. The scattered photons form an azimuthal distribution based on the incident direction and polarisation angle of photons. This azimuthal distribution contains polarisation information and is analyzed with the help of Geant4 simulations, which are an essential part of polarisation analysis. We used different analysis techniques, namely the modulation curve and template fitting methods, to analyze the data. We have shown that both these methods yield similar results in the case of off-axis data with a limited number of Compton events. Our analysis demonstrated that pixelated CZT detectors similar to those used in AstroSat-CZTI are capable of carrying out polarisation measurements upto an incidence angle of $\sim$60 deg. However, at incidence angles between 45 deg and 60 deg, some systematic effects might need to be considered when interpreting the measured PF. It would be possible to improve the results for angles of $\sim$60 deg with further optimization in the analysis and modeling. However, in the practical case of CZTI GRBs with a limited number of Compton events, the systematic effects are expected to be less significant compared with the statistical uncertainties, allowing CZTI to study GRB prompt emission with angles of up to $\sim$60 deg. At an incidence angle $>$60 deg, the CZTI-type pixelated detectors do not have high enough sensitivity for off-axis polarimetry.

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This work is done in collaboration with T. Chattopadhyay (Stanford University, USA), A. R. Rao (TIFR, Mumbai), V. Bhalerao (IIT Bombay), D. Bhattacharya (IUCAA Pune, Ashoka University).

(C. S. Vaishnava, N. P. S. Mithun, S. V. Vadawale, E. Aarthy, A. R. Patel, H. L. Adalja, N. K. Tiwari, and T. Ladiya)

Extending the energy range of AstroSat-CZTI up to 380keV with compton spectroscopy

The CZTI (Cadmium Zinc Telluride Imager) onboard AstroSat is a high energy coded mask imager and spectrometer in the energy range of 20$-$100 keV. Above 100 keV, the dominance of Compton scattering cross-section in CZTI results in a significant number of 2-pixel Compton events and these have been successfully utilized for polarisation analysis of Crab pulsar and nebula (and transients like Gamma-ray bursts) in 100$-$380 keV. These 2-pixel Compton events can also be used to extend the spectroscopic energy range of CZTI up to 380 keV for bright sources. However, unlike the spectroscopy in primary energy range, where simultaneous background measurement is available from masked pixels, Compton spectroscopy requires blank sky observation for background measurement. Background subtraction, in this case, is non-trivial because of the presence of both short-term and long-term temporal variations in the data, which depend on multiple factors like earth rotation and the effect of South Atlantic Anomaly (SAA) regions etc. We have developed a methodology of background selection and subtraction that takes into account for these effects. Here, we describe these background selection and subtraction techniques and validate them using spectroscopy of Crab in the extended energy range of 30$-$380 keV region, and compare the obtained spectral parameters with the INTEGRAL results. This new capability allows for the extension of the energy range of AstroSat spectroscopy and will also enable the simultaneous spectropolarimetric study of other bright sources like Cygnus X-1. We have outlined methods (see Figure 23) for Compton spectroscopy using AstroSat-CZTI where we have developed a technique for Compton background selection and subtraction considering the short-term and long-term temporal variations in data. Applying this technique, we have improved the spectroscopic sensitivity of the CZTI at higher energies for on-axis sources. We use the single-pixel mask-weighted spectral data in the 30$-$100 keV energy range (SE) and 2-pixel Compton events in the 100$-$380 keV energy range (CS) for a joint 30$-$380 keV broad-band spectroscopy. As a proof of concept, we applied this analysis for Crab and compared the spectral parameters with the INTEGRAL/SPI reports.

For the background subtraction, the selection of blank sky data is done by comparing the longitudinal variation of the spectral hardness of the source and blank sky data for the initally selected blank sky observations based on RA-Dec, exposure and BAT flux level. However, the presence of short-term and longterm temporal variation in the observed count rates due to high charge particle concentration in the SAA regions and earth rotation, respectively, make the subtraction of background non-trivial and complicated. To exclude the short-term variation, we ignore the data from -135° to 45° longitude, where the earths magnetic field is relatively weak compared to other regions. The long term variation, on the other hand, is corrected by comparing the phases of the Crab and the

selected background and scaling the overall background count rate according to the count rate observed in the matched phase. While this method ensures correct estimation of background (and source) flux, the background selection procedure makes sure that the selected blank sky background and the original background embedded in the source observation follow the same spectral energy distribution The spectral analysis of the Crab using these techniques using a broken power- law (bknpower in XSPEC) showed that CZTI has sufficient flux sensitivity to perform spectroscopy for on-axis bright sources up to 380 keV. For the single event and Compton event spectra in 30380 keV (SE and CS), the lowenergy slope (PhoIndx1) and higher energy slope (PhoIndx2) agree reasonably with the INTEGRAL/SPI result.

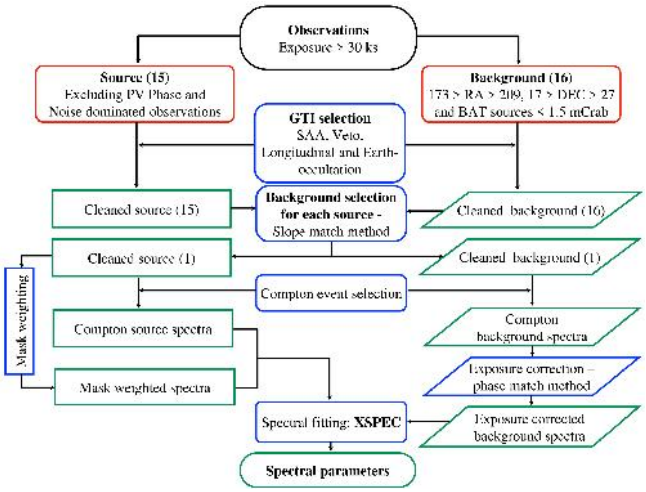

Figure 23: Crab spectral analysis flow chart. The red box shows the initial conditions for selecting 15 source regions and 16 background regions. The blue box is for the process, the green rectangular box represents the source outputs, and the green parallelograms represent the background outputs.

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This work is done in collaboration with T. Chattopadhyay (Stanford University, USA), R. Rao (TIFR, Mumbai), V. Bhalerao (IIT Bombay), D. Bhattacharya (IUCAA Pune, Ashoka University).

(A. Kumar, S. V. Vadawale and N. P. S. Mithun))

PRL 2.5-m Project

A cutting-edge technological endeavour undertaken by the Physical Research Laboratory (PRL) in partnership with Advanced Mechanical and Optical Systems (AMOS), Belgium, is the PRL 2.5m telescope project (Figure 24). The telescope site acceptance test (SAT) was successfully completed in mid-October 2022 (see Table. 1) and since then it is fully operational. The telescope, which is the first of its kind in the nation, has the most cutting-edge active optics and first order seeing corrections employing a tip/tilt unit operating at a frequency of 20Hz. A hyperbolic concave primary mirror (M1) and a hyperbolic convex secondary mirror (M2) share a shared conical focus in the telescope's main tube's Ritchey-Chretien (RC) arrangement. The telescope's plate scale is 10.313 arcsec/mm. The telescope's effective focal ratio is f/8, and its usable waveband ranges from 370 to 4000 nm. The active optics systems' M1 mirror, which is 2.56 metres in size, is supported by 42 axial and 18 peripheral pneumatic actuators. In order to adjust for aberrations, the secondary mirror M2 is positioned over a hexapod and has five degrees of freedom (tip, tilt, and focus). The main port of the telescope has a 25 arcmin diameter unvignetted Field-of-View (FOV). For a FOV with a 10 arcmin diameter, two side ports are intended. The central light is directed to two side ports using two M3 mirrors mounted over rack and pinion support systems. The telescope can be pointed with an accuracy of 4 arcsecs rms absolute and 0.5 arcsecs rms differential. The telescope's tracking precision in a close loop is 0.2 to 0.3 arcsec rms with the auto-guider unit. The CCD imager, also known as the Faint Object Camera (FOC), the PARAS-2, a fiber-fed optical high resolution spectrograph, and the Speckle Imager are the first light-based scientific instruments that are attached with the telescope. Figure 25 shows the exterior view of the PARAS-2 instrument, while Figure 26 shows the image of a Galaxy taken with FOC. Left panel of Figure 27, shows the 2.5-m telescope along with the FOC and PARAS2 instrument, while the right panel shows the images taken during SAT with lucky imaging mode.

S. No	Parameters	Requirement as per contract	Obtained results
Pointing Accuracy			
1	Absolute	2 arcsec RMS	1.88 arcsec RMS
2	Differential	0.5 arcsec RMS	0.446 arcsec RMS
Tracking Accuracy			
3	Open-Loop 1 min	0.2 arcsec RMS	0.134 arcsec RMS
4	Open-Loop 10 min	0.5 arcsec RMS	0.135 arcsec RMS
5	Close-Loop 60 min	0.2 arcsec RMS	0.185 arcsec RMS
Image Quality			
6	Wave Front Error	70 nm RMS + Seeing degradation	64 nm RMS with Shack Hartmann WFS
7	Full Width at Half Maximum(FWHM)	0.35 nm RMS + Seeing degradation	0.18 arcsec (Lucky Imaging)

Table.1 : Site Acceptance Test (SAT) results of the PRL 2.5m telescope

Figure 24: The exterior view of the 2.5-meter telescope at the Mount Abu Observatory.

Figure 25: PRL Advanced Radial-velocity Abu-sky Search (PARAS) -2 working at 110000 resolution in optical wavelengths, the highest resolution spectrograph in India for exoplanet search and characterization.

Figure 26: From PRL 2.5m Telescope SDSS r-band image of NGC 295 about 250 million light years away; 300sec exposure with FOC on 16th October 2022. (Seeing =1.1 arcsec). The faintest star in the field is $\sim$ 20.5mag and sky background is 21st mag per arcsec. Moon was 50 degrees away and was at 60% of its brightness.

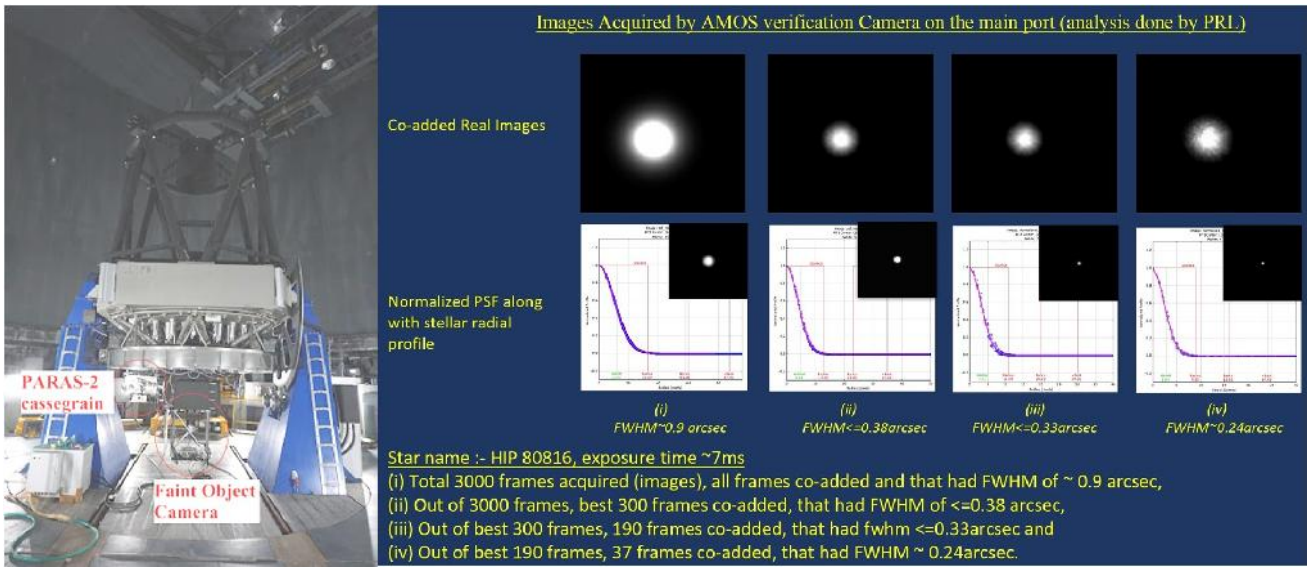

Figure 27: On the left, the fully assembled PRL 2.5m telescope at Gurushikhar Observatory, Mount Abu, India. The FOC is attached to the main port and the PARAS-2 Cassegrain unit is attached to side port#1, can be seen here. On the right, lucky imaging data acquired by AMOS during the SAT are shown.

(Abhijit Chakraborty, Kapil Kumar, Neelam JSSV Prasad, Kevikumar Lad, Ashirbad Nayak, Vivek Kumar Mishra, Nafees Ahmed, Nikitha Jitendran, Vishal Joshi, Mudit K. Srivastava and Rishikesh Sharma)

PARAS-2 instrument for the 2.5 m telescope

We have successfully coupled the PARAS-2 (PRL Advanced Radial-velocity Abu-sky Search) spectrograph with PRL's newly commissioned 2.5m telescope at Gurushikhar Observatory, Mount Abu, in mid of April 2022. The Cassegrain unit of the spectrograph is now attached with the telescope side port#1. The spectrograph is the highest-resolution spectrograph in the country and Asia with a median Resolution of $\sim$ 110,000, in the wavelength range of 380-690 nm (Figure 28, left panel), aimed to detect super-Earths around bright G & K dwarf stars. The spectrograph efficiency is $\sim$ 25%, and the total efficiency including earth's atmosphere and the telescope is $\sim$ 4%. The whole spectrograph is kept inside a thermally controlled vacuum chamber, in which temperature and pressure are maintained at 22.5 $\pm$0.0007°C and 0.001$\pm$0.0005 mbar, respectively. With this precise thermal control, the spectrograph has consistently shown a relative fiber drift of $\sim$ 30 cm s^{-1} for 12 hours, which is evident of the spectrograph's capability to be able to go down to 50 cm s^{-1} precision with stars, necessary for discovering the super-Earths. Currently, we are observing the RV standard stars with the spectrograph to establish the on-sky instrumental precision. For data reduction, we have developed a custom pipeline called the PARAS2 pipeline, which is based on the algorithms of PARAS pipeline. The pipeline does all the necessary corrections like bias and dark subrations, order tracing, scattered light correction and the cosmic ray rejections, before doing the optimal extraction of the spectra from each fiber. For the wavelength calibration purpose, we are using a linelist of uranium lines emerging from Uranium-Argon hollow cathode lamps (Figure 28, right

panel). We have identified and characterized $\sim$ 3000 of Uranium lines and incorporated them in the PARAS2 pipeline and analysis framework. Using these lines, our instrumental stability results are shown below (Figure 29). In near future, the Atmospheric Dispersion Corrector (ADC) unit designed in PRL will be placed in the Cassegrain Unit to correct for atmospheric dispersions.

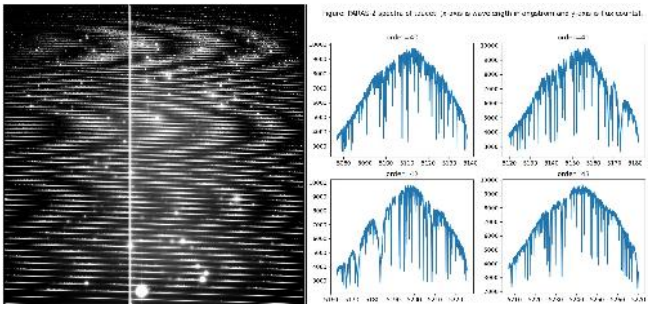

Figure 28: The PARAS-2 echellogram with one fiber is illuminated by the starlight and the fiber illuminated by Uranium-Argon (UAr) hollow cathode lamp is shown on the left. Right panel is showing the reduced/extracted spectra of a star using the PARAS2 pipeline.

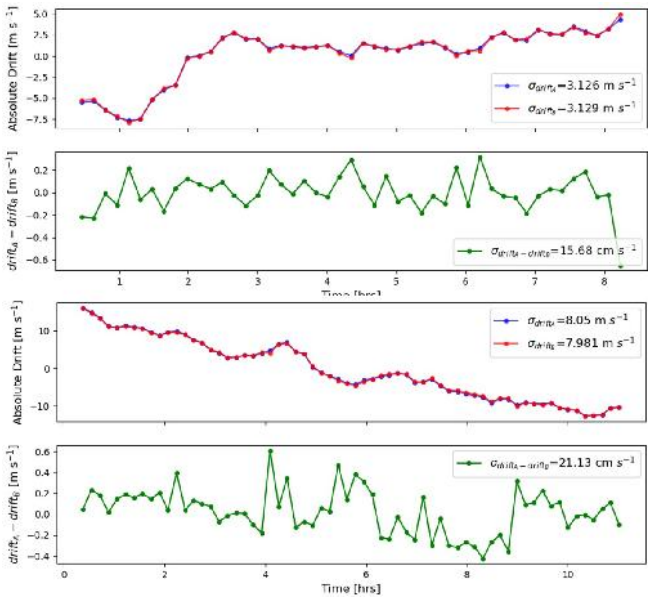

Figure 29: Instrumental drift for two different days calculated using the multiple exposures of UAr in both the fibers. Upper panel is showing the absolute drift of individual fibers, while the lower panel is showing the relative drift between the fibers.

(Abhijit Chakraborty, Kapil Kumar, Neelam JSSV Prasad, Kevikumar Lad, Ashirbad Nayak, Rishikesh Sharma, Sanjay Baliwal and Nikitha Jitendran)

Faint Object Camera

The Faint Object Camera (FOC) is one of the first light instruments for the 2.5m Telescope at Mount Abu Observatory and has been in extensive use since October 2022 including site-acceptance tests of the telescope. It is attached to the main port of the telescope and is used to acquire images and obtain photometry of astronomical objects in the optical and NIR parts of the spectrum. FOC has 5 different available filters, namely u, g, r, i, and z. These filters are similar to the traditional SDSS filterset but have better transmission. The comparison figure of filter transmission curves of the Traditional SDSS filter and the FOC filterset is given in Figure 30.

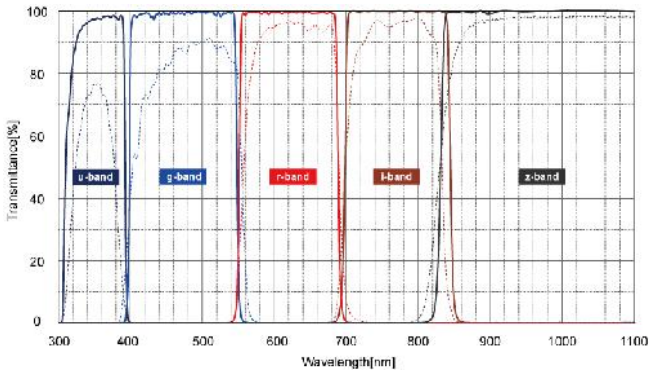

Figure 30: Comparison of Transmission of traditional SDSS filters and FOC filters. The dashed lines are traditional SDSS ugriz bands whereas solid lines are FOC filters.

FOC uses a 4k $\times$ 4k back-illuminated ANDOR CCD with 15 micron pixel size as a detector. The CCD can be cooled to -100°C to reduce the dark current, which is about 0.0008 e/pix/sec. The read noise is approximately 2.1 e @ 100 kHz read rate, and the quantum efficiency is better than 95%. The Field-of-View of FOC is 10 arcmin $\times$ 10 arcmin. With a 10-minute exposure time, FOC can detect a 21st mag star in the i filter. It also includes a neutral density filter that can be used to image a bright star without saturating the detector. FOC is a versatile instrument that can be used for various studies, from Solar system objects to extragalactic astronomy. You can see an g filter image of an open star cluster NGC 2420 captured using FOC in Figure 31.

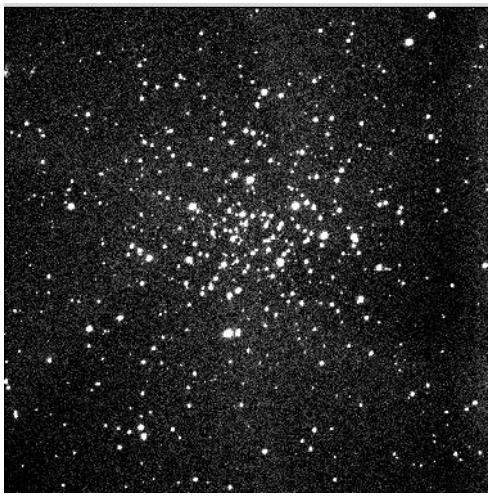

Figure 31: g filter image of an open cluster NGC 2420, captured using FOC on 2.5m Telescope.

(Abhijit Chakraborty, Kevikumar Lad, Neelam JSSV Prasad, Kapil Kumar, Ashirbad Nayak and Vishal Joshi)

Development of Low Resolution Spectrograph

A low-resolution spectrograph is an invaluable tool for any telescope. We are currently in the process of developing such an instrument for the 2.5m Telescope at Mount Abu Observatory. The spectrograph is intended to provide a resolution of 1500-2000 in the wavelength range of 4000-7000 Angstroms. To accomplish this, we will use a beam splitter to divide the telescope light into two beams. The reflected beam, which contains 8% of the light, will be directed toward a CCD that will help us identify the field, center the star in the slit, and guide the telescope in real time. The remaining 92% of the light will pass through a slit and a colimating lens. We will then disperse the colimated beam using a 50mm $\times$ 50mm, 1200 l/mm reflection grating. The dispersed light will be focused onto a 4K $\times$ 4K front-illuminated CCD detector with 9 micron pixel size, which will record the spectrum (Figure 32). The detector has a dark current of 0.02 e/pix/sec at -30$\circ$C and a readnoise of approximately 9 e @ 1 MHz. We will use a halogen lamp and an Ar lamp to obtain the flat field and wavelength calibration data, respectively. The calibration lamps' light beams can be directed in the system using two fold mirrors placed on a linear stage just before the slit. We anticipate being able to obtain a spectrum of a V = 17 mag star with 1 hour of exposure time using LRS. The instrument will be mounted on one of the side ports of the telescope, and it will be suitable for studying a variety of objects, including those in the solar system, stars, and galaxies.

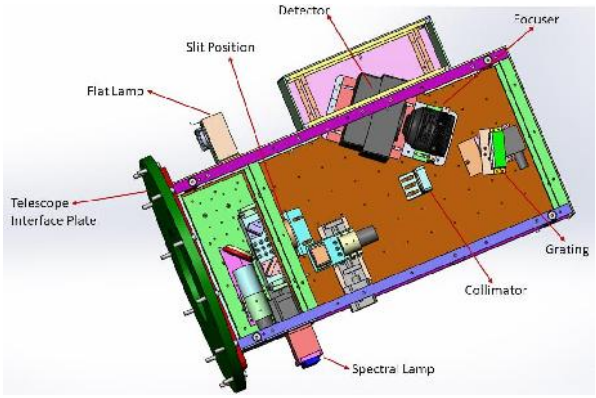

Figure 32: Layout of the Low-Resolution Spectrograph.

(Vishal Joshi, Kapil Bhardwaj, Soumya Kohli, Nafees Ahmed, Kevikumar Lad, and Neelam JSSV Prasad)

Near infrared background with the 1.2 m telescope at Mount Abu

We presented an estimation and analysis of the Near Infrared (NIR) background for the astronomical site at Mount Abu in this publication. Data obtained from the NIR photometric observations of various sources using the Near Infrared Camera/Spectrograph (NICS) on the 1.2 m telescope have been used to derive the NIR background estimates. We noticed seasonal variations in these values, with the summer months showing brighter background compared to the winter (see Figure 32 (top panel)). We also presented a comparison of synthetic atmospheric transmission at Mount Abu with other Indian observatories at various altitudes. We identified the plausible contributors to the NIR background in our observations and discussed the potential ones that can contribute to the noticed seasonal variations. Overall, we found that the NIR background does not show any systematic variation over the period of the observations from 2010 to 2019 (see Figure 33 (bottom panel)). A qualitative modelling (Figure 34) to understand the effects of various factors contributing to NIR sky brightness has also been presented in this paper. This further helps the NIR instrument designers in decision-making.

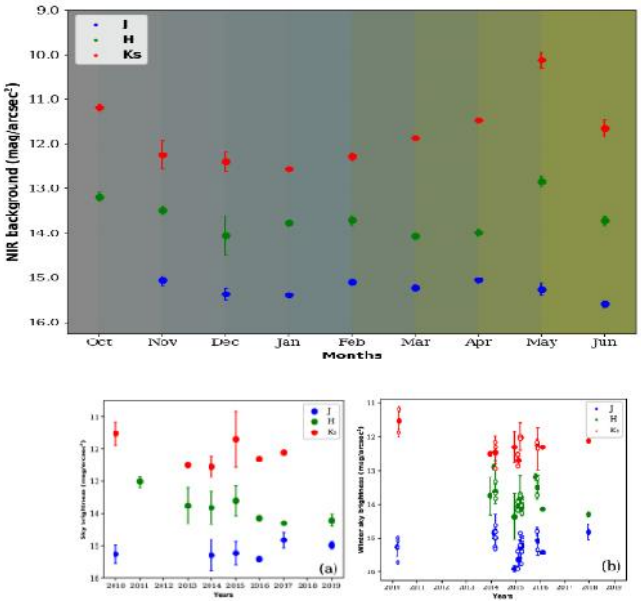

Figure 33: (Top panel) Seasonal variation in the NIR background at Mount Abu observatory. (Bottom left - (a)) NIR Background values (in mag $arcsec^{-2}$) averaged over the nine months (Oct-Jun), for given years. (Bottom right - (b)) The NIR background values (in mag $arcsec^{-2}$) for all the available winter nights of given years are illustrated using empty circles, whereas the filled circles show an averaged value of sky brightness in that year for the winter season.

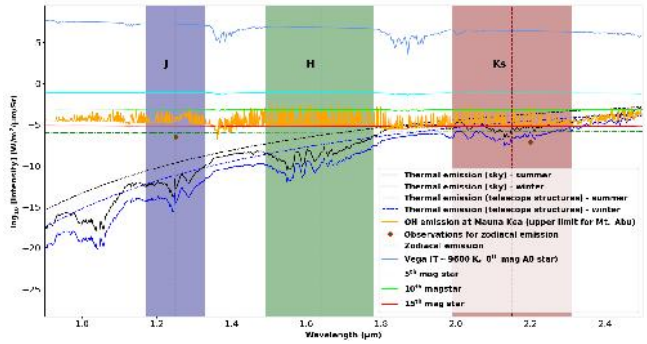

Figure 34: Comparison among various background emissions in NIR for Mount Abu. Bands in violet, green, and brown with dotted central wavelengths show standard J, H, and K_s broadband filters of NIR. Thermal emission from the sky is shown with solid black and blue curves for summer and winter, respectively. Thermal emission from the telescope support structure is shown with black and blue dashed curves for summer and winter, respectively. The OH emission plotted with the yellow solid curve gives an upper limit for Mount Abu based on Mauna Kea Observatory's data. Modelled zodiacal emission (**?**) is plotted with a dark green dash-dotted line. Two observational data points for zodiacal light at 1.25 μm and 2.2 μm are shown using green-filled red circles. Stellar spectra of point sources of magnitudes 5, 10, and 15 are indicated with cyan, lime green, and dark orange solid curves, respectively.

(Prachi Prajapati, Anwesh Mishra, Ananya Rawat, Shashikiran Ganesh, Vishal Joshi, Neeraj Kumari and Sachindra Naik)

NISP instrument development for the 2.5 m telescope

NISP is one of the upcoming back-end instruments for the 2.5 m telescope at Mount Abu Observatory. With the target of having Imaging, Spectroscopy and Polarimetry capabilities, it will cover a wavelength range of 0.9 - 2.5 μm. The instrument will be developed around Teledyne's H2RG detector, which will be cooled to cryogenic temperature (77 K). We are using an H2RG Read Out Integrated Circuit (ROIC) for testing the designed setups and developing an experience of detector handling tools as well as methodology. The ROIC is identical to the detector without the IR sensitive layer. It has some sensitivity in the optical band. At the final stage, ROIC will be replaced by the science grade H2RG detector.

ROIC performance at room temperature:

Figure 35 shows the ROIC being installed on the detector mounting plate (left panel) and the ROIC+SIDECAR ASIC mounted on a base plate (right panel). The frames are taken both in single frame, CDS and Fowler sampling modes. Read noise for individual frames is estimated by measuring the standard deviation over the full frame. The average read noise of 9 frames is calculated for each gain setting. At lower gain the read noise of about 4-10 ADUs is observed at room temperature. At higher gain the read noise is expectedly higher. The resultant images are shown in Figure 36.

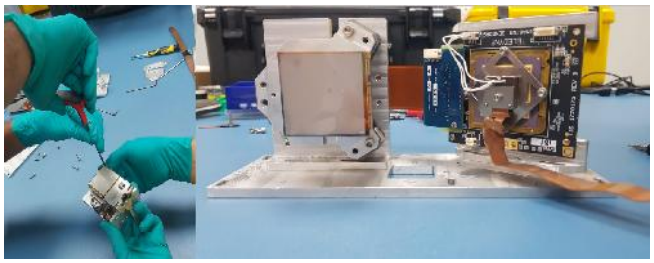

Figure 35: ROIC being installed with the help of handling tool on detector mounting plate (Left) and mounted alongside cryogenic SIDECAR ASIC (Right).

Figure 36: Images taken by the ROIC at room temperature: Radial pattern mask with 1 mm holes (Left), PRL NISP mask(Middle) and Image of Tungsten - lamp filament(Right).

ROIC performance at cryogenic temperature:

For testing the ROIC at cryogenic temperature(78.3 K), we mounted the ROIC and SIDECAR inside vacuum Dewar. SIDECAR acquisition module (SAM) card was mounted outside of Dewar. For interfacing SAM card with SIDECAR, we designed a 6-layer PCB card which was mounted in a vacuum feed-through as shown in Figure 37 (middle). Data transmission from SAM card to PC is done using USB2.0. The final setup is depicted in Figure 38. The images obtained under cryogenic conditions are shown in Figure 39. After acquiring multiple images we found the read noise to be 60 ADU in full frame and 25 ADU in window mode. The full frame dark current was found to be 0.03 ADU/pixel/sec.

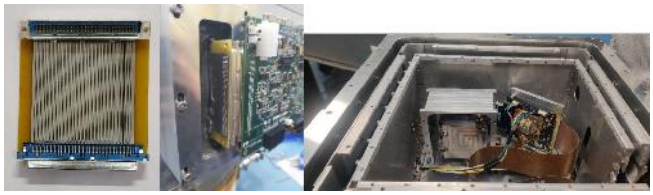

Figure 37: (Left) 200-pin interface board between SAM card and SIDECAR, mounted in Dewar as vacuum feed-through (Middle), ROIC and SIDECAR mounted inside Dewar (Right).

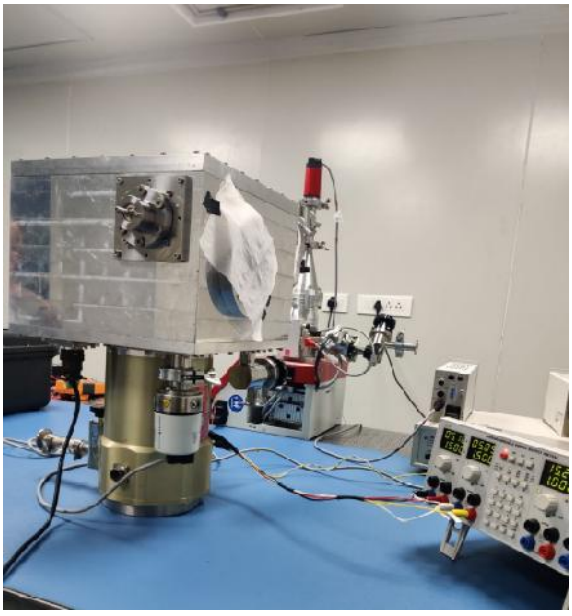

Figure 38: Cryogenic set-up for ROIC and cryogenic SIDECAR.

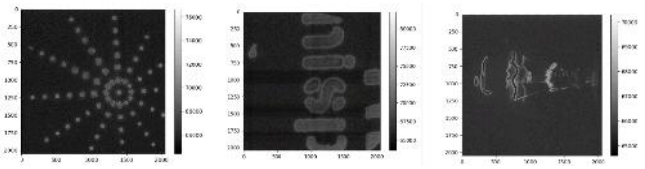

Figure 39: Images taken with ROIC at cryogenic temperature: radial pattern mask with 1 mm hole size (Left), PRL NISP mask (Middle) and Image of Tungsten-lamp filament (Right).

Linearity and stability analysis of setup for characterization of H2RG detector.

An in-house LED and photo-diode test setup is designed for detector characterisation and stability analysis using an Arduino, various LEDs, OPT101 trans-impedance amplifier, and ADS1115 ADC. The plots for the dark current stability and photo-diode output are shown in Figure

40. We have also performed independent checks on LED driving electronics. We used the electronics and various LEDs (as shown in the upper left panel of Figure 41) to check the response of the Teledyne Read Out Integrated Circuit (ROIC) in cryogenic conditions. The image of the LEDs obtained by the ROIC is shown in Figure 41 (upper right). Counts were integrated within the image of each individual LED to check the linearity, and a plot for different LEDs is shown in Figure 41 (lower panel).

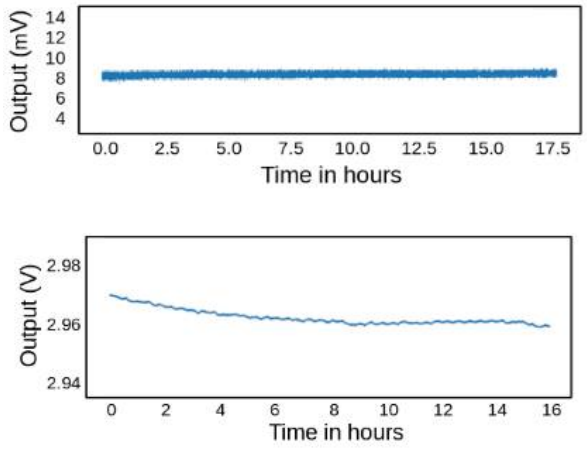

Figure 40: Stability of the dark current of the measured photo-diode (Top) Stability of the complete system including the LED driver and trans-impedance amplifier (Bottom).

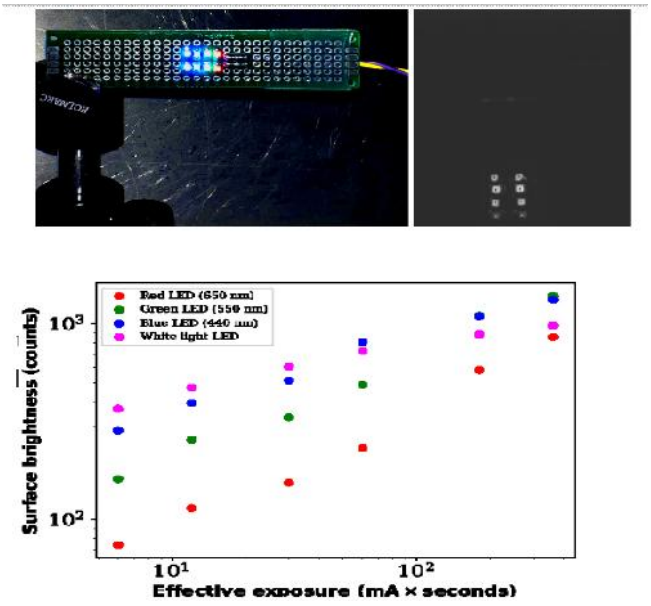

Figure 41: (Top left) Electronics and ROIC used in cryogenic conditions for checking the response of white, blue, green, and red LEDs (Top right) Obtained image (Bottom) Check for the linearity of the LEDs (red, green, blue, and white); X-axis is the effective exposure time in milli-ampere times seconds and Y-axis shows the surface brightness in counts.

(Anwesh Mishra, Alka, Prashanth Kasarla, Deekshya Roy Sarkar, P. S. Patwal, Prachi Prajapati, Hitesh L. Adalja, Sachindra Naik, A. B. Shah, Shashikiran Ganesh, et al. (NISP team))

Adaptive Optics (AO) System Development

The earths turbulent atmosphere introduces wavefront distortions to the light coming from distant stars which results in poor image quality of ground based optical/near-infrared (NIR) telescopes. Using Adaptive Optics (AO) technique, the wavefront distortions can be corrected which results in significant improvement in the image quality. A project for developing an Adaptive Optics (AO) based instrument for the PRL 2.5m telescope has been initiated in PRL. As part of the instrument development process, an AO test-bench setup, which is a scaled down version of the AO system, has also been designed to simulate and characterize various AO subsystems in laboratory-controlled conditions. This year, the entire activity can be described in the following three subsections:

Experimental setup of AO test-bench: Characterization of turbulence chamber and its turbulence properties

The test-bench setup has been designed to simulate the conditions for the PRL 2.5m telescope with the analytical framework of the AO system. The test-bench setup has been designed completely with off-the-shelf components to reduce cost and development time-scale. A hot air-based optical turbulence generator (OTG) is used to simulate a range of input conditions to mimic varying seeing conditions at the observatory. The complete optical layout of the test-bench setup and the actual image of the setup is shown in Figure 42. A collimated beam is made to pass through the OTG in order to introduce proportionally scaled wavefront distortions as present in the incoming light coming from a distant star that passes through the Earths atmosphere and is collected by the 2.5m telescope. The pupil of 2.5m aperture is scaled down to 44mm. This then scales Fried Parameter (r0) of 10 cm to 1.76mm.

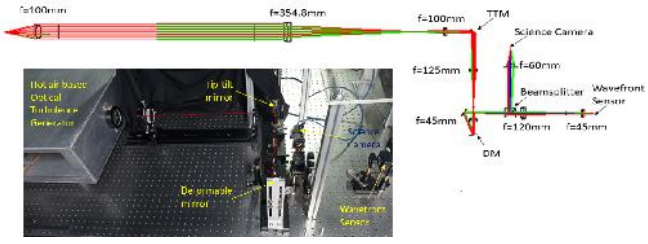

Figure 42: Optical schematic of the AO test-bench setup. Actual setup in the laboratory is also shown.

Optical Turbulence Generator (OTG) Parameter	**Value**
Pupil size	44mm
Maximum temperature difference between hot and cold side	200K
Fried parameter (r_0)	around 1.76mm
Typical D/r_0 at Mt. Abu 2.5m telescope	25
D/r_0 for the turbulence chamber	22-26
D/V during windy conditions at Mt. Abu 2.5m telescope	0.125 s
D/V for the turbulence chamber	0.09-0.45 s

Table. 2 : Characteristic and Simulated parameters of the turbulence in the AO test-bench experiment.

A pupil mapping optical relay converts the pupil size to match the size of the tip-tilt mirror (Physik Intrumente model no. S330K232) of 0.5 inch (12.7mm). This tip-tilt mirror corrects for the course and slow fluctuations in the wavefront. The reflected beam from the tip-tilt mirror passes through another optical relay which maps the pupil size to match with the size of the deformable mirror (Boston Micromachines model no. Multi-3.5-DM) of 4.8mm. The deformable mirror corrects for the fine fluctuations happening at a very fast rate in the wavefront. The reflected beam from the deformable mirror is splitted by a beam-splitter into two fractions. One part of the beam is used to form the image of the source while the other part of the beam is used for wavefront sensing. A shack-Hartmann wavefront sensor (Thorlabs model no. WFS 20-5C) with 11×11 lenslet array (150 μ pitch) is used to sense the amount of the wavefront distortion present in the beam and reconstruct the wavefront. The feedback from the wavefront sensor is sent to the tip-tilt mirror and the deformable mirror to correct for the residual wavefront errors. In this way, the complete closed loop control system is achieved. The parameters for the hot-air based OTG have been given in Table 2. The detailed hardware description of the OTG has been described in the previous annual reports. The OTG is being used to introduce wavefront distortion in the collimated beam which is characterized by the test-bench setup. Figure 43 shows an image of the reconstructed wavefront obtained during laboratory characterization and a reconstructed wavefront obtained from our AO simulation software. AO simulation software has been described in the previous annual reports.

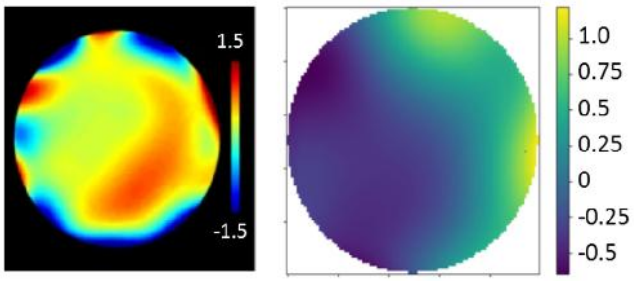

Figure 43: Reconstructed wavefront during laboratory characterization(left), Reconstructed wavefront illustration from our simulation software(right).

Figure 44: Control Electronics for the Automation of the Turbulence chamber in AO test bench.

An elctronics control card (PCB) (Figure 44) has been developed to automate control of the turbulence generator by adjusting various parameters of the turbulence chamber (like temperature difference, wind speed) via software tool. The PCB has circuitry for various sub systems viz. velocity sensor interfaced with ADC, temperature sensor, PWM module for dc fan, solid state relay operated heater. Interface to Raspberry Pi is provided from each of the aforementioned modules, as shown in Figure 45 block diagram. Communication is established via SPI protocol. It has been ensured to optically isolate sensor signals from Raspberry Pi signals. The PCB has been tested in the lab and is used to characterize the turbulence generated by the OTG.

Development of Closed Loop Controls for AO System

In an AO instrument, a control system is used to extract the wavefront sensor signals and compute the feedbacks that are to be sent to the Deformable Mirror and Tip-tilt mirror.

Parameters	**PC 1 (to provide user interface) Specifications**	**PC 2 (for AO closed loop control) Specifications**
Processor	Intel Xeon 4210R	AMD Ryzen Threadripper PRO 3955WX
Number of cores per processor	10	16
Processor Base Frequency (GHz)	2.4	3.9
RAM Size(GB)	32	32
OS	CentOS 7 with graphical interface	CentOS 7 without graphical interface
L1, L2, L3 cache sizes	640KB, 10MB, 13.8MB	1MB, 8MB, 64MB
Number of GPU cards	1	2
Number of CUDA cores per GPU card	896	5888
Networking Controller	1GbE(to be used for LAN), 10GbE (to be used in IPC)	1GbE(to be used for LAN), 10GbE (to be used in IPC)

Table. 3 : Specifications of the Workstations used for Closed Loop control development of AO system.

An AO control system has to operate at a very fast rate in order to match the characteristic time-scale of the atmospheric turbulence. The basic architecture of the AO control system has been mentioned in the previous year annual report. Currently, the two PC methodology is being implemented for AO control system realization. In this architecture, one of the PCs would provide a user interface to carry out auxiliary instrument-related operations, while the second PC would be utilised to run real-time AO control software. The specifications of both the PCs are given in Table-3. Socket programming based interprocess communication (IPC) method is used for data transfer and control. The IPC works in the TCP client server mode. On the server side as well as the client side, three different sockets are created to accept requests for three different types of functionalities viz user command transfer, data stream transfer, continuous update function. These are implemented using string transfer, chunked array transfer and file

transfer methods. For handling multiple client requests simultaneously, various methods viz. forking, select and threading were explored. It is finally being implemented using multithreading. We have made use of semaphores to avoid multiple threads overwriting. The block diagram shown in Figure 46 provides an overview about communication layer implementation between two PC systems for PRL AO real-time control system.

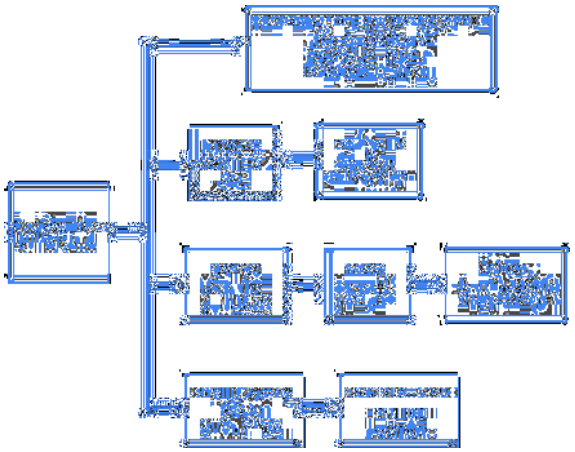

Figure 45: Block Diagram of the OTG parameters control electronics.

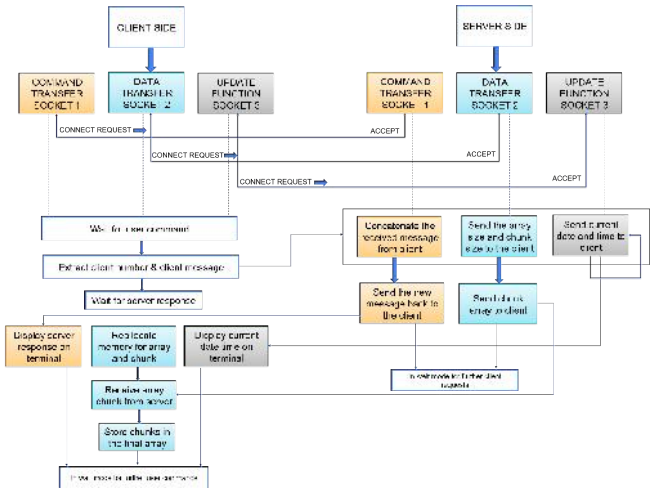

Figure 46: Communication layer implementation between two PC system.

Updates on Adaptive Optics (AO) Assisted Near-Infrared (NIR) Camera for PRL 2.5m Telescope

The proposed AO assisted NIR camera instrument is being designed for a 30 arc-second field of view and would be able to work with both Natural Guide Star (NGS) as well as with artificial Laser Guide Star (LGS). Base optical design had been presented in the previous annual report. The design has witnessed further optimization to achieve the desired image quality. Apart from the wavefront distortion, airs wavelength-dependent refraction coefficient has an impact on differential atmospheric refraction. In other words, earths atmosphere acts as a prism which causes the formation of an image spectrum in the direction of telescope altitude. Thus, the image appears to be elongated when observed through broadband filters, leading to the loss of spatial resolution. An atmospheric dispersion corrector (ADC) can correct for the dispersion caused by the earths atmosphere by causing the same amount of dispersion in the opposite direction. We are going to use a rotating double Amici prism-based design as an ADC for our instrument. The ADC is made up of two identical prism assemblies, but arranged in opposite directions. Both the prism assemblies can be synchronously rotated about the optic axis with the same amount but in the opposite direction to each other. Figure 47 shows the design of our ADC prism assembly.

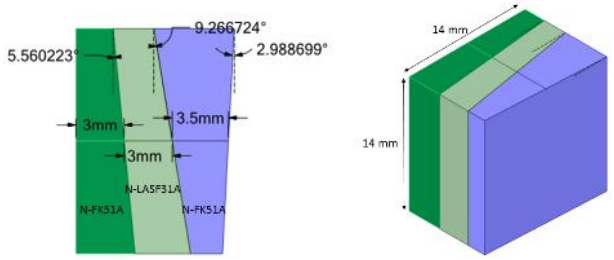

Figure 47: Optical design of one of the prism of ADC. Each ADC prsim consists of three wedge-shaped glass plates cemented together.

Each of the ADC prism assemblies consists of three wedge-shaped glass plates cemented together. The glasses have good transmission over the designed wavelength range between 0.4 μ to 2.2 μ. The ADC prisms would be kept near tip-tilt mirror position where the beam diameter is around 10mm. The optical design of the ADC was simulated using Zemax optical design software. In order to take atmospheric dispersion into account, the Zemax subroutine “Atmospheric” has been utilized which considers Zenith angle, observatory altitude, latitude, temperature, pressure and humidity in simulating atmospheric dispersion. The prism has been designed in such a way that at zenith angle z=65 degree, the prisms get aligned at prism angle=0 degree thus adding the dispersion of both prisms which ultimately cancels the atmospheric dispersion. Apart from the prism angle, ADC prisms also need to be given a constant DC rotation to take care of rotation of field arising due to the Alt-Azimuth telescope. Figure 48 shows the prism angle of the ADC vs. Zenith angle of the telescope.

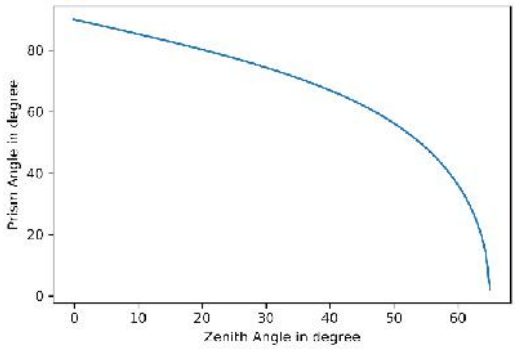

Figure 48: The optimal ADC prism angle as a function of zenith angle. ADC has been designed.

(Vaibhav Dixit, Ankita Patel and Mudit K. Srivastava)

Development of Mt. Abu Faint Object Spectrograph and Camera - Echelle Polarimeter (M-FOSC-EP) for PRL 2.5m Telescope

Mt. Abu Faint Object Spectrograph and camera Echelle Polarimeter (M-FOSC-EP) is a two-channel multimode instrument currently being designed for the PRL 2.5m telescope at Mt Abu. M-FOSC-EP offers the facility for the seeing limited filter-based imaging, low-resolution spectroscopy using grisms, and intermediate resolution spectro-polarimetry in visible waveband (3900-9900 angstroms). The system would utilize a common collimator optics to couple the low-resolution (R$\sim$500-800) module and higher-resolution (R$\sim$15000) spectro-polarimeter modules using a movable fold mirror utilizing two separate detector systems.

The optical design and various science parameters were discussed in previous years annual reports. Here we describe the development on the mechanical design aspects of the instrument. The instrument is being designed as a Cassegrain port instrument which has volume restrictions of around 1m $\times$ 1m and weight constraints of nearly 340 Kg. A preliminary CAD model of the mechanical design is shown in Figure 49.

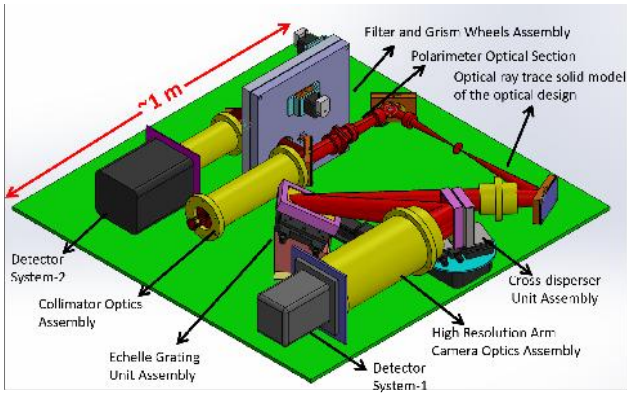

Figure 49: Preliminary mechanical design (CAD model) of M-FOSC-EP instrument. Major sub systems are shown. The mechanical design of the instrument is currently underway.

The layout is being conceptualized on an optical bench on dimension 1m $\times$ 1m where all the major optical sub-systems are being mounted. The optical lens system of the common collimator optics would be mounted inside a single lens barrel which collimates the light beam. A motorized fold mirror in the collimated space would direct the beam into the low-resolution arm of the instrument, wherein the beam would pass through the filter and grism units. Another fold mirror is added in the design to fold beam in the low-resolution arm into the low-resolution camera optics and finally on to the detector system-2 $-$ an EMCCD camera system. In the high-resolution mode of the instrument, the beam from the collimator is allowed to pass directly into the polarimeter optical section, where after passing through a half-waveplate and a Wollaston prism the beam would be bifurcated into two orthogonal polarised o and e beams. With the help of two-fold mirrors, both the beams are directed onto the Echelle grating and cross-disperser sub-system.

The dispersed beams from the cross-disperser unit would enter into the high-resolution camera optics barrel and finally be recorded on the detector system-1 - a 2K $\times$ 2K CCD camera system. The preliminary layout is optimized with fold mirrors to design the entire instrument within the volume constraints of the Cassegrain port of the 2.5m telescope.

(Mudit K. Srivastava, Vaibhav Dixit, Bhaveshkumar Mistry, Arijit Maiti, Ankita Patel, and Vipin Kumar)

Development of ProtoPol : A Prototype Spectro-polarimeter

ProtoPol is the prototype spectro-polarimeter which has been designed to simulate and test some of the critical hardware sub-systems of the M-FOSC-EP instrument such as Echelle grating and cross-disperser gratings, polarisation optics set-up etc. Utilizing commercially available off-the-shelf (COTS) optical components, ProtoPol is developed as a standalone instrument in itself, which can be used on PRL 1.2m as well as on 2.5m telescope with minimal interface change. ProtoPol has been designed to provide spectral resolutions of 6000-7000 in 3820-9660 angstroms wavelength range. The optical and opto-mechanical designs of ProtoPol were presented in previous years reports. Here we are describing the mechanical assembly of the instrument. The mechanical systems of the instrument have been developed completely in-house utilizing PRL workshop facility.

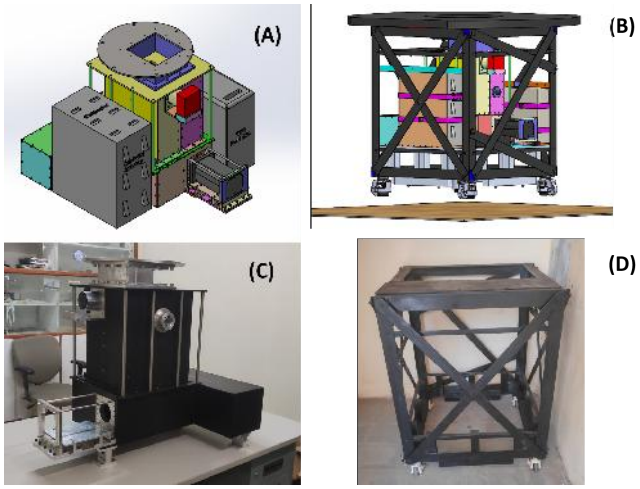

Figure 50: CAD model and Fully assembled mechanical system of ProtoPol. (A) CAD model of ProtoPol instrument assembly, (B) CAD model of ProtoPol assembly within telescope interface for 2.5m telescope, (C) Fully assembled mechanical system of ProtoPol, and (D) Telescope Interface system of ProtoPol for 2.5m telescope.

The modular design of the mechanical system of ProtoPol ensures the ease of its assembly and integration in the laboratory and transportation to the observatory. The mechanical system consists of three major modules namely; (1.) the Polarimeter unit, (2.) the spectrometer unit and (3.) the calibration unit. In addition, another telescope interface unit is also added to its mechanical structure to couple the instrument to 1.2m/2.5m telescopes Cassegrain plate. An off-axis auto guider unit is designed within this top-interface.

The light from the telescope is focused on to its focal plane inside the polarimeter unit, which is then collimated and refocused by a set of 5 lenses, and 3 mirrors in addition to few more specialized optical

components (such as Wollaston prism and Half wave plate). Custom designed mechanical holders provide required alignment accuracies to the lenses. Polarimeter unit also contains a linear motorized stage for calibration optics, a motorized rotation stage (with 1:70 reduction ratio) for half-wave plate and a small linear stage for a bandpass filter. The last mirror of this unit directs light into the spectrometer unit section. The spectrometer unit consists of a parabolic collimator mirror, an echelle grating and two cross-dispersers gratings. Mounting platforms for all these components were designed and fabricated considering various assembly and alignment aspects of the system. These mounting platforms are custom designed to hold tip-tilt alignment stages with mechanical locking provisions. The cross-dispersers gratings are mounted on two motorized linear stages with guide rails. The light from the polarimeter unit is first collimated and then dispersed before entering into the Camera unit which is equipped with an off-the-shelf Canon camera lens system and ANDOR CCD detector system. The calibration unit module is designed to provide a calibration light beam from three spectral lamps for spectral calibration ProtoPol. All the mounts for lenses, mirrors, gratings, etc. are made from Aluminium 6061T material and are black anodized. Two different telescope interfaces are developed for 1.2m and 2.5m telescope. These interfaces are made from SS-304 material. The fully developed mechanical system of ProtoPol and the telescope interface are shown in Figure 50 along with their CAD model.

(Mudit K. Srivastava, Bhaveshkumar Mistry, Arijit Maiti, Vaibhav Dixit, Ankita Patel, Vipin Kumar and Kevikumar Lad)

Solar Physics

Sustained Heating of the Chromosphere and Transition Region Over a Sunspot Light Bridge

The solar chromosphere serves as an important conduit for mass and energy between the dense,6000 K photosphere and the tenuous, million degree corona. The solar chromosphere has a complex magnetic structure, where the plasma beta changes dramatically (Gary 2001). Determining the processes that maintain the thermal structure of the solar atmosphere is one of the fundamental problems in solar physics. The energy transfer in the chromosphere can be attributed to a number of mechanisms, such as Alfv́en waves (Osterbrock 1961), spicules (Beckers 1968), nanoflares (Priest et al. 2018), magneto-acoustic shocks (De Pontieu et al. 2015), and resistive Ohmic dissipation by electric currents (Parker 1983, Socas-Navarro 2005, Louis et al. 2021). In this study we attempt to ascertain the source of sustained heating over several days in the chromosphere and transition region above a sunspot light bridge (LB). We combine observations from the Multi-Application Solar Telescope (MAST), the Interface Region Imaging Spectrograph (IRIS), Hinode, the Atmospheric Imaging Assembly (AIA), and the Helioseismic and Magnetic Imager (HMI).

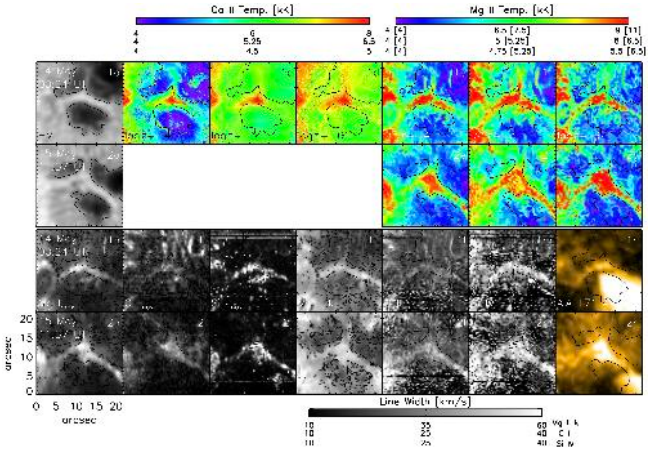

Figure 1: Top row, from left to right: HMI continuum intensity (panel a), temperature derived from the MAST Ca II IR line (panels bd), and temperature derived from the IRIS Mg II line (panels e-g). The numbers from the top to the bottom row below the temperature color bar represent $\log\tau = -6$, -5, and -4, respectively. The temperature color bar for the IRIS Mg II line is similar, with the numbers in the parentheses corresponding to the observations on 2019 May 15 at 11:57 UT for the maps in the second row. Second row: the same as above on 2019 May 15 at 11:57 UT. Third row: maximum line intensity from the IRIS Mg II line, C II line, Si IV line (panels h-j), line width from the IRIS Mg II line, C II line, Si IV line (panels k-m), and AIA intensity at 171 Å (panel n) on 2019 May 14. Bottom row: the same as above on 2019 May 15 at 11:57 UT. The black contours correspond to the HMI continuum intensity and outline the LB.

Chromospheric temperatures were retrieved from the MAST Ca II IR and IRIS Mg II lines by non-local thermodynamic equilibrium (NLTE) inversions. Line widths, Doppler shifts, and intensities were derived from the IRIS lines using Gaussian fits. Coronal temperatures were estimated through the differential emission measure, while the coronal magnetic field was obtained from an extrapolation of the HMI vector field. At the photosphere, the LB exhibits a granular morphology with field strengths of about 400 G and no significant electric currents. The sunspot does not fragment, and the LB remains stable for several days. The chromospheric temperature, IRIS line intensities and widths, and AIA 171 and 211 Å intensities are all enhanced in the LB with temperatures from 8000 K to 2.5 MK that follow the underlying photospheric morphology. Photospheric plasma motions remain small, while the chromosphere and transition region indicate predominantly redshifts of 520 km s^{-1} with occasional supersonic downflows exceeding 100 km s^{-1}. The persistent heating over the LB is counterintuitive as the underlying structure would radiate the majority, if not all, of its energy once having evolved to a strongly convective region inside the sunspot. The excess thermal energy over the LB is about 3.2×10^{26} erg and matches the radiative losses. It could be supplied by magnetic flux loss of the sunspot (7.5×10^{27} erg), kinetic energy from the increase in the LB width (4×10^{28} erg), or freefall of mass along the coronal loops (6.3×10^{26} erg). It remains an open question whether such persistent heating over a large height range in a granular LB is indeed a generic phenomenon.

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(Rohan E. Louis, Shibu K. Mathew, Raja Bayanna)

A study of the propagation of magnetoacoustic waves in small-scale magnetic fields using solar photospheric and chromospheric Dopplergrams: HMI/SDO and MAST observations

Acoustic waves are generated in the convection zone of the Sun via turbulent convection, and compressibility provides the restoring force. These waves are trapped inside acoustic cavities beneath the solar photosphere formed due to abrupt decrease in density at the photosphere and high temperature inside the Sun. The acoustic cut-off frequency of the quiet-Sun photosphere is 5.2 mHz (Bel & Leroy, 1977), which is estimated from $\omega_{ac} = c_s/2\mathrm{H}_\rho$, where c_s and H_ρ are the photospheric sound speed and density scale height, respectively. It is well known that acoustic waves above the cut-off frequency (5.2 mHz) can propagate up to the solar chromosphere, while waves of lower frequencies ($<$ 5.2 mHz) are evanescent. However, this condition is altered by the magnetic fields, which affect the propagation of these waves. In the presence of magnetic fields, plasma β is low $\beta < 1$, and acoustic cut-off frequency (ω_{ac}) is changed by $\cos(\theta)$ (Bel & Leroy, 1977), where θ is the angle between magnetic fields with respect to the direction of gravity (which is normal to the solar surface). Acoustic waves of frequency $\nu < 5.2$ mHz are

believed to intermittently interact with the background magnetic fields resulting in episodic signals.

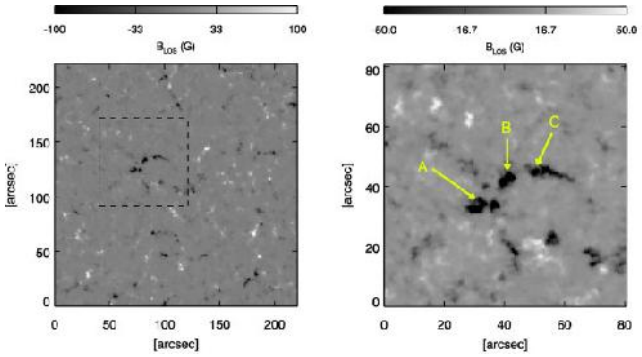

Figure 2: Sample maps of average of photospheric line-of-sight magnetograms over 112 min duration (left panel), and blow up region of a strong magnetic network region (right panel) as denoted by black dashed square box in the left panel. Line-of-sight (LOS) magnetogram has been saturated at $\pm$100 G and $\pm$50 G, respectively, to bring out the small-scale magnetic features. The yellow arrows with labels 'A', 'B' and 'C' show the identified locations for the investigation of leakage of low-frequency ($<$ 5.2 mHz) oscillations.

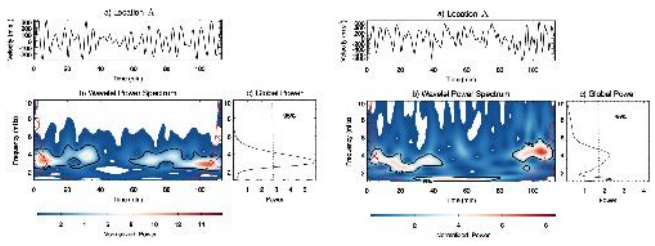

Figure 3: Left panel: Upper panel (a) shows the temporal evolution of average velocity signals obtained from the photospheric Dopplergrams for location A. The bottom panel shows the WPS and the GWPS in (b) and (c), respectively, computed from the velocity time series. In the WPS, the solid lines demonstrate regions with the 95% confidence level, and the hatched region indicates the cone of influence. The color scale represents the wavelet power. The dotted line in GWPS shows a confidence level at 95%. Right panel: Same as left panel, but from chromospheric velocity for location A as estimated from MAST observations.

We explore the propagation of low-frequency magneto-acoustic waves into the solar chromosphere within small-scale inclined magnetic fields over a quiet-magnetic network region utilizing near-simultaneous photospheric and chromospheric Dopplergrams obtained from the HMI instrument onboard SDO spacecraft and the Multi-Application Solar Telescope (MAST) operational at the Udaipur Solar Observatory, respectively. In order to detect these episodic signals, we apply the wavelet transform technique to the photospheric and chromospheric velocity oscillations in magnetic network regions (c.f. right panel of Figure 2). The wavelet power spectrum over photospheric and chromospheric velocity signals show a one-to-one correspondence between the presence of power in the 2.54 mHz band (c.f. Figure 3). Further, we notice that power in the 2.54 mHz band is not consistently present in the chromospheric wavelet power spectrum despite its presence in the photospheric wavelet power spectrum. This indicates that leakage of photospheric oscillations (2.54 mHz band) into the higher atmosphere is not a continuous process. The average phase and coherence spectra estimated from these photospheric and chromospheric velocity oscillations illustrate the propagation of photospheric oscillations (2.54 mHz) into the solar chromosphere along the inclined magnetic fields. Additionally, chromospheric power maps estimated from the MAST Dopplergrams also show the presence of high-frequency acoustic halos around relatively high magnetic concentrations (c.f. Figure 4), which are considered to be due to the refraction of high-frequency fast mode waves around v_s = v_A layer in the solar atmosphere.

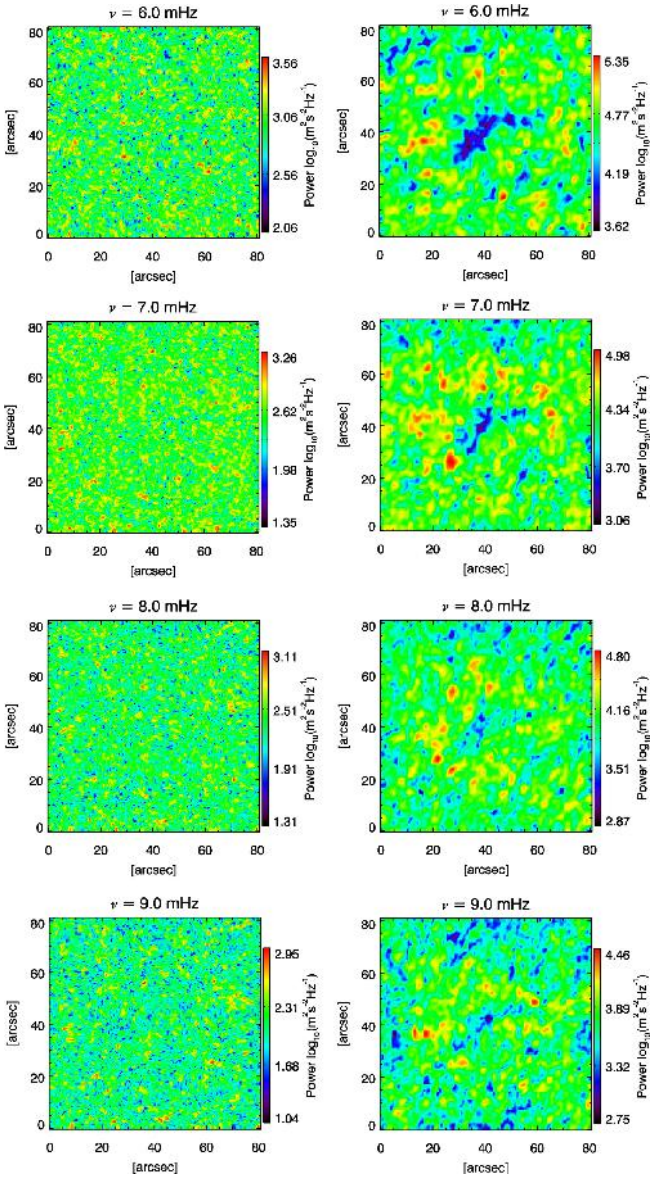

Figure 4: Left panel: Power maps at different frequencies constructed from photospheric velocity oscillations obtained from HMI instrument over a small strong magnetic network region as shown in the right panels of Figure 2. Right panel: Same as left panel but from chromospheric velocity oscillations estimated from MAST observations.

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This work has been done in collaboration with S. P. Rajaguru of Indian Institute of Astrophysics, Bengaluru.

(Hirdesh Kumar, Brajesh Kumar, Shibu K. Mathew, and Ankala Raja Bayanna)

Calibration and performance evaluation of a monomorph deformable mirror

To achieve diffraction-limited performance with a 50 cm solar telescope at the Udaipur solar observatory the development of a high-order adaptive optics (AO) system is currently in progress. The system includes a monomorph deformable mirror (MDM) with 85 actuators and 35 mm diameter that servers as a wavefront corrector. Prior to using the MDM in an AO system, the MDM is calibrated, and its performance is evaluated using a laboratory source. Aim is to determine the extent of intrinsic aberrations of the MDM and the optimum voltage vector that makes the MDM optically flat, so that the MDM can be used in the optical setup without introducing any aberrations. For this purpose, a laser interferometer is used to calibrate the MDM. The performance of the MDM is evaluated using the laser interferometer and ShackHartmann wavefront sensing (SHWFS) mechanism.

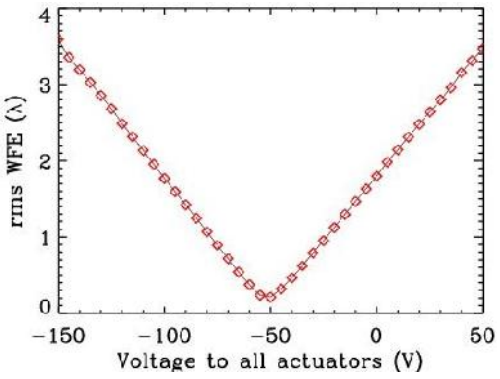

Figure 5: rms wavefront error (WFE) measured with the application of a constant voltage to the all the actuators,It is evident that the DM exhibits defocus error when there is no voltage applied to any actuator and it is free of intrinsic defocus error at -50 V and the rms wavefront error is significantly reduced. However, this value changes to about -75 V when the mirror is operated in reverse direction due to hysteresis.

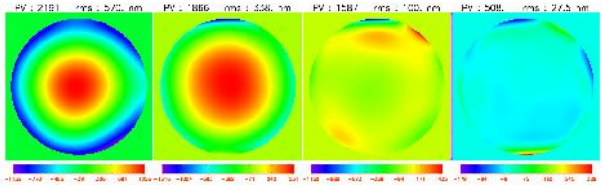

Figure 6: Closed-loop correction of aberrations using SHWFS. It is evident that the rms WFE reduced from 570 nm to 27 nm for an input aberration.

From the calibration it is understood that DM shows intrinsic curvature, and it can be corrected by applying -50 V to all the actuators that makes the DM almost flat and the residual wavefront error is minimum as shown in Figure 5. By estimating the influence matrix and operating the mirror in closed loop this intrinsic error of DM reduced further with voltages to all the actuators varying around -50 V. Closed-loop correction of intrinsic aberration using SHWFS is shown in Figure 6.

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(A Raja Bayanna, Bireddy Ramya, Shibu K. Mathew, Rohan E. Louis)

An effective generalized mechanism responsible for the production of broad CMEs resulting from compact solar eruptive flares

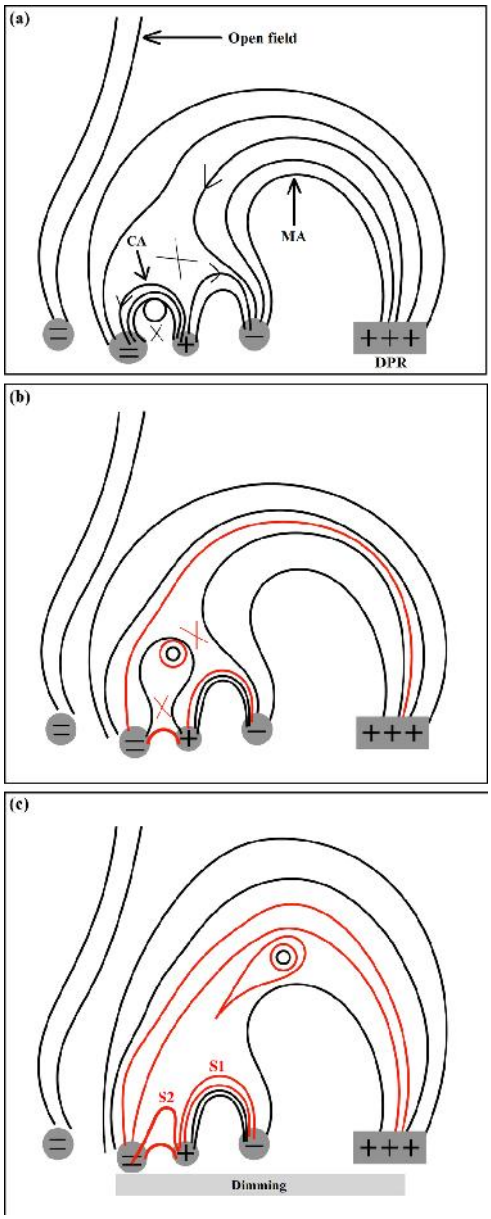

Figure 7: Schematic representation of the MAB scenario for the production of broad CMEs resulting from homologous compact major blowout eruptions, viewed from solar west. Panel (a): the large magnetic arch (MA) connects the distant positive-polarity region (DPR) and the negative flux region of the AR. The large negative sunspot of the AR is denoted by circles with double negative signs, from where the open field lines also originate. On the right of the large sunspot, we show a compact bipolar region hosting the compact arcade (CA), enveloping the flux rope. On the right of CA, we show another set of field lines, which connect the compact region and a larger negative flux region, situated north of the compact region. The plausible reconnection sites are marked by cross signs. Panel (b): the reconnection between CA and MA, weakens the MA field lines and creates a pathway for the eruption of the flux rope. Panel (c): the external reconnection between CA and MA produces the set of field lines labeled S1, and the internal reconnection between the legs of the field lines stretched by the erupting flux rope creates the set of field lines labeled S2. The brightening in the outer footpoints of the S1 field lines is observationally confirmed by the wide circular ribbon structure, whereas the S2 field lines exhibit themselves as compact postflare loop arcades. The extent of the dimming resulting from the blowout eruption of MA is also indicated in panel (c).

Coronal mass ejections (CMEs) exhibit a range of shapes and sizes in view of their complex morphological structures. CMEs are designated as homologous when they originate from the same location of an active region with similar morphological resemblances in coronagraphic observations. Here, we analyze the formation mechanism of three homologous broad CMEs resulting from a series of solar blowout-eruption flares with successively increasing intensities (M2.0, M2.6, and X1.0). The flares originated from NOAA Active Region (AR) 12017 during 2014 March 2829 within an interval of ≈24 hr. Coronal magnetic field modeling based on nonlinear force-free field extrapolation helps to identify low-lying closed bipolar loops within the flaring region enclosing magnetic flux ropes. We obtain a double flux rope system under closed bipolar fields for all the events. The sequential eruption of the flux ropes led to homologous flares, each followed by a CME. Each of the three CMEs formed from the eruptions gradually attained a large angular width, after expanding from the compact eruption-source site. We find these eruptions and CMEs to be consistent with the magnetic-arch-blowout (MAB) scenario (see Figure 7): each compact-flare blowout eruption was seated in one foot of a far-reaching magnetic arch, exploded up the encasing leg of the arch, and blew out the arch to make a broad CME. The occurrence of large EUV coronal dimming observed in the wake of the eruptions supports this scenario.

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(Suraj Sahu, Bhuwan Joshi, and Prabir K. Mitra)

Evolution of magnetic fields and energy release processes in an efficient magnetically coupled solar atmosphere

The fundamental processes that drive solar eruptive events are inherently guided by the complexity of the solar magnetic fields. Therefore, in order to understand the drivers of solar flares and their associated processes, it is important to analyze the variability in the buildup and release of magnetic energy. In this study, we explore the processes of the repetitive buildup and the explosive release of magnetic energy, together with the formation of magnetic flux ropes, which eventually resulted in three homologous eruptive flares of successively increasing intensities (i.e., M2.0, M2.6, and X1.0). The flares originated from NOAA AR 12017 between 2014 March 28 and 29. EUV observations and magnetogram measurements, together with coronal magnetic field modeling, suggest that the flares were triggered by the eruption of flux ropes that were embedded in a densely packed system of loops within a small part of the active region. In X-rays, the first and second events show similar evolutions, with single compact sources, while the third event exhibits multiple emission centroids, with a set of strong nonthermal conjugate sources at 50-100 keV during the hard X-ray peak. Over an interval of 44 hr, the photospheric magnetic field encompassing the three flares undergoes important phases of emergence and cancellation, together with significant changes near the polarity inversion lines within the flaring region (FR) (see Figure 8). Our observations point toward the tether-cutting mechanism being the plausible triggering process of the eruptions. Between the second and third events, we observe a prominent phase of flux emergence that temporally correlates with the buildup phase of free magnetic energy in the active region corona. In conclusion, our analysis reveals efficient coupling between the rapidly evolving photospheric and coronal magnetic fields in the active region, leading to a continued phase of the buildup of free energy, which results in the homologous flares of successively increasing intensities.

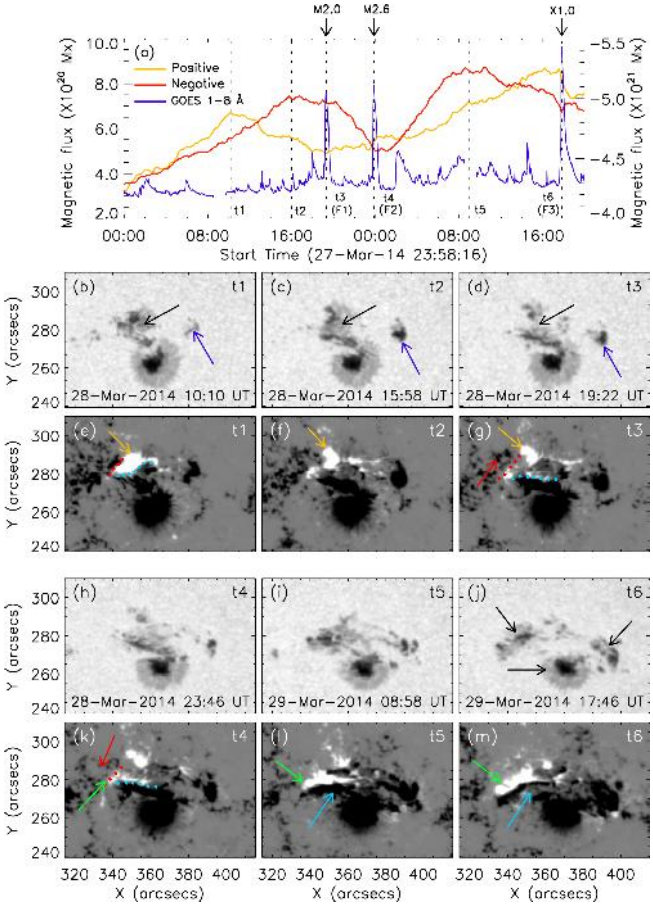

Figure 8: panel (a): the temporal evolution of the magnetic flux obtained from the FR, along with the GOES SXR light curve in the 1-8 channel. Panels (b)–(d): intensity images of the FR at three instances - t1, t2, and t3 - as marked in panel (a). The black arrows denote small-scale changes in the northern sunspot group, while the blue arrows indicate the growth of a compact sunspot group. Panels (e)–(g): LOS magnetogram images that are co-temporal with the continuum observations (shown in the row above) at times t1, t2, and t3, respectively. The yellow and red arrows are used to indicate the changes in the positive and negative fluxes, respectively. Panels (h)–(j): intensity images of the FR at t4, t5, and t6, as marked in panel (a). The arrows in panel (j) indicate three distinct sunspot groups. Panels (k)–(m): LOS magnetogram images for t4, t5, and t6 that are co-temporal with the corresponding continuum observations (shown in the row above). The yellow (see panels (e)–(g)) and red (see panels (g) and (k)) arrows are used to indicate the changes in the positive and negative fluxes, respectively. The green and sky blue arrows are used to indicate the changes in positive and negative fluxes, respectively. The red and sky blue dotted lines in panels (e), (g), and (k) denote the PILs in the eastern and western parts of the FR, respectively.

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This work was done in collaboration with Avijeet Prasad (University of Oslo, Norway) and Kyung-Suk Cho (Korea Astronomy and Space Science Institute, Republic of Korea).

(Suraj Sahu and Bhuwan Joshi)

Near-Earth Interplanetary Coronal Mass Ejections and Their Association with DH Type II Radio Bursts During Solar Cycles 23 and 24

Coronal mass ejections (CMEs) consist of large-scale structures containing magnetised plasma expelled from the solar corona into the interplanetary medium. CMEs and their interplanetary counterparts (ICMEs) are known to be associated with a variety of other important phenomena, such as solar energetic particle (SEP) events, interplanetary (IP) shocks, geomagnetic storms (GS), which form essential ingredients of the current space weather research. It is well established that the Earth-directed CMEs are the primary cause of severe geomagnetic storms. Only a fraction of CMEs can produce the magnetohydrodynamic shock, subsequently giving rise to type II radio bursts. In this context, it is worth mentioning that the extension or origin of a type II radio burst in the decameter-hectometer (DH: 30 MHz $\leq$ f $\leq$ 300 kHz) domain implies the cases of stronger MHD shocks propagating from the inner corona and entering the IP medium. It is worth to mention that the CMEs causing DH type II radio bursts have a larger angular width and the majority are halo CMEs. Therefore, the study of ICMEs with respect to their association with DH type II radio bursts is extremely valuable to probe their invisible interplanetary propagation and possible geomagnetic consequences. Therefore, we aim to broaden our understanding of the properties and propagation characteristics of ICMEs in terms of their association (type II ICMEs) versus absence (non-type II ICMEs) of DH type II radio bursts during Solar Cycles 23 and 24. The present investigation becomes feasible due to an almost uninterrupted data set of IP type II radio bursts encompassing the two complete solar cycles. Further, the availability of a CMEICME catalogue provides us with a unique opportunity for an in-depth exploration of interrelations between CMEs, ICMEs, and geomagnetic storms. We find a drastic reduction in the occurrence of ICMEs by 56% in Solar Cycle 24 compared to the previous cycle (64 versus 147 events). Interestingly, despite a significant decrease in ICME/CME counts, both cycles contain almost the same fraction of type II ICMEs (≈47%). Our analysis reveals that, even at a large distance of 1 AU, type II CMEs maintain significantly higher speeds compared to non-type II events (523 km s^{-1} versus 440 km s^{-1}). While there is an obvious trend of decrease in ICME transit times with increase in the CME initial speed, there also exists a noticeable wide range of transit times for a given CME speed. Contextually, Cycle 23 exhibits 10 events with shorter transit times ranging between 2040 hours of predominantly type II categories while, interestingly, Cycle 24 almost completely lacks such fast events. Geomagnetic storms produce a strong disturbance on the horizontal component of the global geomagnetic field, which is conventionally measured by the disturbance storm time index (Dst index). It is well established that the Dst minimum is directly linked to the southward component of the interplanetary magnetic field. In-situ measurements have revealed that ICMEs approaching the Earth (with speed V_{ICME}) can possess long intervals of southward magnetic field (B_z) which critically influence the energy transfer into the Earths magnetosphere. The studies also point toward the fact that ICMEs cause relatively stronger response to the ring current index Dst. To assess the geoeffectiveness of ICMEs, we primarily explore the relation of the Dst index, with V_{ICME} and B_z . In Figures 9a and d, we present the correlation between Dst index and B_z for non-type II and type II events for Solar Cycles 23 and 24, respectively. An examination of the correlation coefficients in different plots suggests a good correlation between the two parameters in all the cases. There is a noticeable difference in the correlation coefficients of Dst index versus B_z plots for non-type II and type II cases for Cycle 23 (0.85 versus 0.59), which is due to the wide spread in Dst values for a given B_z, suggesting a much complex interplay of ICME and Earths magnetosphere for individual type II associated events. The correlations of V_{ICME} with Dst index are presented in Figure 9b and e, which suggest a weak (for Cycle 23) or no correlation (for Cycle 24). In Figure 9c and f, we explore the correlation between Dst index and $V_{ICME} \times B_z$. The quantity $V_{ICME} \times B_z$ is essentially the dawn-to-dusk electric field imposed by the solar wind plasma and interplanetary magnetic field (IMF) on the Earths magnetosphere. Importantly, the parameter $V_{ICME} \times B_z$ shows a strong correlation with Dst index for all the cases, which even surpasses the consideration of B_z or V_{ICME} alone. In this context, we note a significant difference of $V_{ICME} \times B_z$ values between the type II and non-type II events for both cycles. We further find a significant reduction in the parameter $V_{ICME} \times B_z$, the dawn to dusk electric field, by 39% during Solar Cycle 24 in comparison with the previous cycle. The above results imply the crucial role of $V_{ICME} \times B_z$ toward effectively modulating the geoeffectiveness of ICMEs.

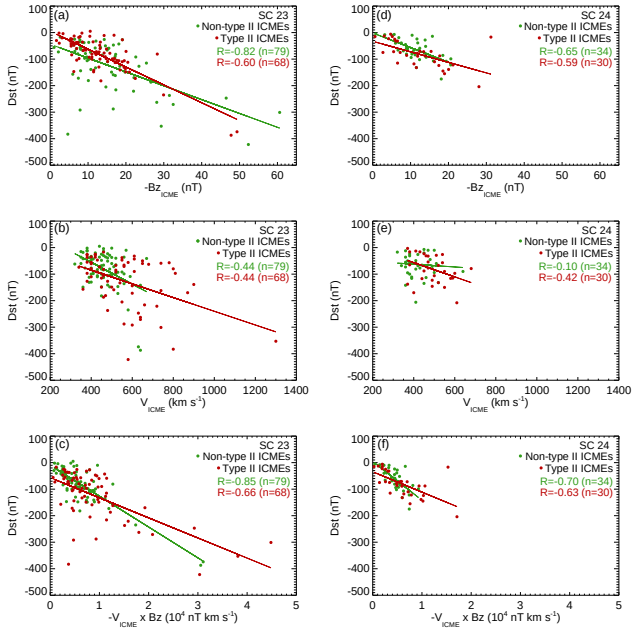

Figure 9: Correlation plot between the minimum southward magnetic field (B_z), ICME speed (V_{ICME}), and $-V_{ICME} \times B_z$ with the Dst index for Solar Cycles 23 (left panel) and 24 (right panel). The red and green symbols represent the type II and non-type II ICMEs, respectively. n denotes the number of data points in each panel. R in each plot indicates the Pearson correlation coefficient for linear regression line.

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This work was done in collaboration with Dr. Kyung-Suk Cho (Korea Astronomy and Space Science Institute, Daejeon 34055, Republic of Korea), Dr. Rok-Soon Kim (Korea Astronomy and Space Science Institute, Daejeon 34055, Republic of Korea) and Dr. Yong-Jae Moon (Kyung Hee University, Yongin, Republic of Korea).

(Binal Patel, Bhuwan Joshi)

Comparison of the Hall Magnetohydrodynamics and Magnetohydrodynamics Evolution of a Flaring Solar Active Region

This work analyzes the Hall magnetohydrodynamics (HMHD) and magnetohydrodynamics (MHD) numerical simulations of a flaring solar active region as a test bed while idealizing the coronal Alfvn speed to be less by two orders of magnitude. HMHD supports faster magnetic reconnection and shows richer complexity in magnetic field line evolution compared to the MHD. The magnetic reconnections triggering the flare are explored by numerical simulations augmented with relevant multiwavelength observations. The initial coronal magnetic field is constructed by non-force-free extrapolation of photospheric vector magnetic field. Magnetic structure involved in the flare is identified to be a flux rope, with its overlying magnetic field lines constituting the quasi-separatrix layers (QSLs) along with a three-dimensional null point and a null line. Compared to the MHD simulation, the HMHD simulation shows a higher and faster ascent of the rope together with the overlying field lines, which further reconnect at the QSL located higher up in the corona. The footpoints of the field lines match better with the observations for the HMHD case, with the central part of the flare ribbon located at the chromosphere. Additionally, field lines are found to rotate in a circular pattern in the HMHD, whereas no such rotation is seen in the MHD results. Interestingly, plasma is also observed to be rotating in a cospatial chromospheric region, which makes the HMHD simulation more credible. Based on the aforementioned agreements, HMHD simulation is found to agree better with observations and thus opens up a novel avenue to explore.

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This work has been done in collaboration with Dr. Avijeet Prasad (Institute of Theoretical Astrophysics, University of Oslo, Postboks 1029, Blindern NO-0315 Oslo, Norway), Dr. Qiang Hu (Center for Space Plasma & Aeronomic Research, The University of Alabama in Huntsville, Huntsville, AL 35899, USA)

(Kamlesh Bora, Ramit Bhattacharyya and Bhuwan Joshi)

Effects of Initial Conditions on Magnetic Reconnection in a Solar Transient

Solar transients such as solar flares and Coronal Mass Ejections (CMEs) are believed to be driven by the fundamental process of magnetic reconnection. Understanding transients necessitates the modeling of magnetic fields in the solar atmosphere. Broadly, force-free and non-force-free methods are employed in modeling depending on whether the allowed Lorentz force is zero or not. Extrapolated magnetic fields are routinely employed to simulate the dynamics of transients via numerical simulations. Therefore, it is imperative to assess the influence of extrapolation models on the simulated dynamics. In this work, we select active region NOAA 11977, hosting a C6.6 class eruptive flare. Observations from SDO/AIA and SDO/HMI are utilized to explore the spatiotemporal evolution of the flare. The extrapolated magnetic field from both the models are suitably used to generate three different initial conditions for the MHD simulations. An initial morphological comparison of the extrapolated magnetic fields on global and particularly for selected topologies, such as a magnetic null point and a hyperbolic flux tube (HFT), suggests that similar magnetic field line structures are reproducible in both models, although the extent of agreement between the two varies. The three simulations are compared for dissipated free magnetic energy and changes in magnetic field line connectivity due to reconnection at the magnetic null point and the HFT. The comparison reveals that changes are similar across all the simulations, thus suggesting near independence of the simulated dynamics with respect to the initial conditions. The most important result of this work is the spontaneous generation of a magnetic null point (Figure 10) near the location of HFT in all the three simulations. Notably, the fan plane of this generated null was seen to undergo slipping reconnection, thus contributing towards the observed brightenings. The results confirm the near-independence of simulated dynamics with respect to initial conditions. Therefore, both the extrapolation techniques can be suitable for initiating data-driven and data-constrained simulations.

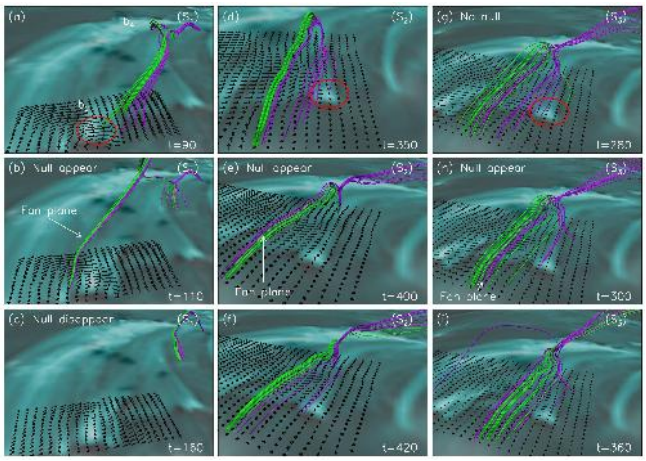

Figure 10 : Snapshots from the simulated evolution of selected green and purple magnetic field lines to illustrate the contribution of spontaneously generated magnetic null in the observed brightening for simulations S1, S2, and S3. The first row shows initial field line configuration, just before the instance of null point generation. The red circle indicates the region of interest in terms of observed brightening while the black arrows represent the flow velocity vectors. Second row highlights the footpoint movement of the fan plane, which does not follow the direction of plasma flow (black arrows). The third row depicts the instance where the null point is lost in time. The bottom boundary is overlaid with line-of-sight magnetogram from SDO/HMI at 02:48 UT along with an image of AR11977 from SDO/AIA in 131 Åchannel at 02:59:56 UT.

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(Satyam Agarwal and Ramit Bhattacharyya)

Magnetic reconnections as the underlying cause of spontaneous generation and annihilation of three-dimensional magnetic nulls

Three-dimensional (3D) magnetic nulls are preferential sites for triggering solar coronal transients. Although these nulls are abundant in the solar atmosphere, their generation is yet to be thoroughly

explored. This paper explores the mechanism of null generation as well as annihilation in detail by means of implicit large eddy simulations where magnetohydrodynamic equations are solved in the absence of an explicit magnetic diffusivity. The magnetofluid is idealized to be thermodynamically inactive, incompressible, and have perfect explicit electrical conductivity. The simulated dynamics is initiated by a prescribed flow in a magnetic configuration having an isolated current-free 3D null. The flow facilitates reconnections, which lead to the generation of primary null pairs in a way that preserves the topological degree. The formation process of these null pairs is novel and different from the standard pitchfork bifurcation. Contrarily, here we found creation of null pairs away from the central null, which we hypothesize is due to the interaction of the imposed flow and the reconnection outflow from the central current layer. Intriguingly, further evolution spontaneously generates new null pairs, which have a novelty by itself. As theorized, these spontaneously generated null pairs also preserve the net topological degreeadding credibility to the simulation. The simulation also shows null pair annihilation. Magnetic reconnections are identified to be responsible for the generation and annihilation of the nullsopening the possibility for the nulls to be self-organized structures. Furthermore, the reconnection being ubiquitous in the corona, it can explain the coronal abundance of magnetic nulls.

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This work has been done in collaboration with David Ian Pontin (School of Information and Physical Sciences, University of Newcastle, Callaghan, NSW 2308, Australia

(Yogesh Kumar Maurya and Ramit Bhattacharyya)

A Parametric Study of Performance of Two Solar Wind Velocity Forecasting Models During 20062011

State-of-the-art MHD space weather forecasting frameworks are based upon the Potential Field Source Surface (PFSS) and Schatten Current Sheet (SCS) extrapolation models for the magnetic field using synoptic magnetograms. These models create a solar wind (SW) background for the simulations using empirical relations of Wang, Sheeley and Arge (WSA), at the inner boundary of heliosphere and have been used to simulate coronal mass ejections for specific cases in previous studies. Besides these MHD frameworks, the Heliospheric Upwind eXtrapolation (HUX) technique can extrapolate SW from inner heliospheric boundaries to L1 and can give a reliable estimate of the SW velocity at L1 comparable to MHD models but in a short computational time. A framework for forecasting solar wind parameters at L1 point using two different models, Model1 (PFSS+WSA+HUX) and Model2 (PFSS+SCS+WSA+HUX) has been developed. We applied this framework to 60 Carrington Rotations from CR2047 to CR2107 during 20062011, spanning the declining and deep minimum phase of solar cycle 23 and the ascending phase of the solar cycle 24. These models use synoptic magnetograms of the GONG network to create the background solar wind. The solar wind velocities estimated using the two models have been compared with observed solar wind velocities by in-situ spacecraft like ACE and Wind at L1. The performance of this framework has been found to be consistently good in general, except in the deep solar minimum. The decreased performance of the framework in the solar minimum has been explained in terms of lower coronal hole area observed during that period. As SC 24 began, this decreasing trend vanished due to an increase in the coronal hole (CH) area at the low and mid-latitudes, suggesting a good correlation between the performance of the framework and the variation in the CH area as shown in Figure 11. We suggest that the framework performance can be improved for the deep minimum case if reliable observations of the magnetic field near the poles can be obtained or by using an extrapolation method on a regular θ grid for PFSS and SCS. Further, relative contributions of various factors affecting the framework performance need to be explored for the deep minimum period, that is, the curvature of polarity inversion line (PIL), CH area at low-mid latitudes, and the errors in the magnetic field extrapolation method.

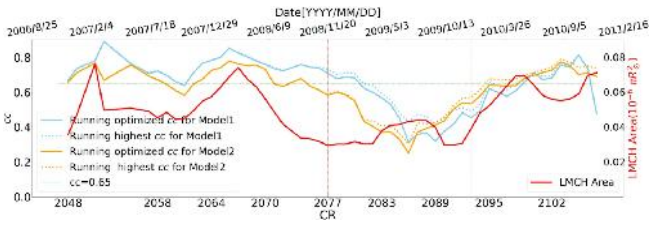

Figure 11: Running average of low-mid latitudes coronal hole (LMCH) area of six Carrington Rotations (CRs), derived from SOHO/EIT 19.5 nm channel synoptic maps (shown in Red) and running average of cc, of simulated solar wind velocity with the observed solar wind velocity, for Model1 (Sky Blue) and Model2 (Orange).

doi : https://doi.org/10.1029/2022SW003069

(Sandeep Kumar and Nandita Srivastava)

Solar Hysteresis Pattern and Spectral Components in TEC Time Series (GPS and TIE-GCM) of the Quadrilaterally Coupled Geomagnetic Conjugate Low-latitude Stations

Using the Total Electron Content (TEC) time series from the Global Positioning System (GPS) and Thermosphere Ionosphere Electrodynamics General Circulation Model (TIE-GCM) for the period 2009-2017 over pairs of geomagnetic conjugate low latitude stations, this work was carried out to determine how sea-locked versus land-locked lower atmospheric conditions, latitudinal location of stations, and hemispheric asymmetry affect TEC variability and the inherent periods of TEC trends, as well as understand the potential physical relationships for observed TEC periodicities. The F10.7 flux and TEC measurements of solar cycle-24 have revealed the presence of the well-known Gnevyshev gap and solar hysteresis (Figure 12). The seasons, local time, longitude and latitude all have an effect on the pattern of solar hysteresis. In the case of GPS TEC, land-locked northern low-latitude stations [Varanasi (25.31°N; 82.97°E) and LHAZ (29.65°N; 91.10°E)] exhibit clockwise hysteresis, whereas sea-locked stations [DGAR (7.27°S; 72.37°E) and COCO Island (12.18°S; 96.83°E)] exhibit mix-up hysteresis. TIE-GCM shows clockwise hysteresis at all stations.

The Lomb-Scargle periodogram analysis shows that the improved TIE-GCM version 2.0, which incorporates variable eddy diffusion to provide an accurate simulation of seasonal variability, is largely successful in simulating semi-annual and annual oscillations but still needs to resolve the seasonal anomaly feature, particularly in the case

of southern low latitude stations. Terannual (120-day) and 1.4-year (500-day) periodicities in the TEC time series are observed only at EIA region stations, not at off-crest location LHAZ, and are most likely caused by E x B drift. The F10.7 flux and TEC (GPS and TIE-GCM) time series at all stations had QBO periodicities of 587-, 730-, and 773-day. However, the spectral peak at 930-day is obtained in the F10.7 flux and GPS TEC time series only, and it did not appear in the TIE-GCM time series at any of the stations.

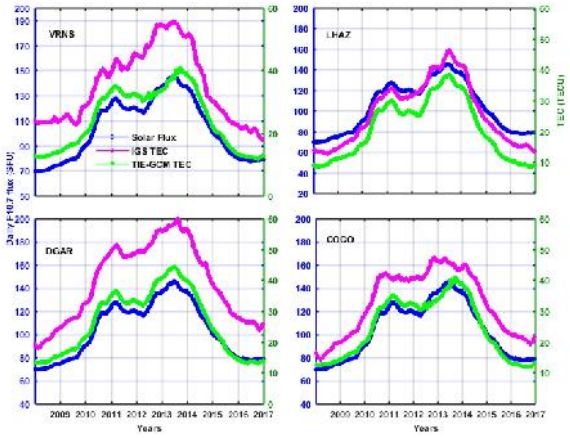

Figure 12. The solar cycle variation of the 365-day centered running mean of F10.7 flux indices (blue curve), GPS TEC (pink curve), and TIE-GCM TEC (green curve) is shown. The left ordinate gives the scale of F10.7 flux, and the right ordinate gives the scale of TEC.

The wavelet coherence analysis has also been used to identify the cause of the QBO oscillation in TEC, which reveals that the TEC QBO oscillations are highly coherent and in-phase with the QBO oscillation of the F10.7 flux (Figure 13). The wavelet coherence analysis revealed no clear correlation between TEC and QBO oscillations in geomagnetic activity. Nevertheless, in a few cases, some episodic and out-of-phase relationships exist. So, variations in solar activity are the primary source of ionospheric QBO oscillations.

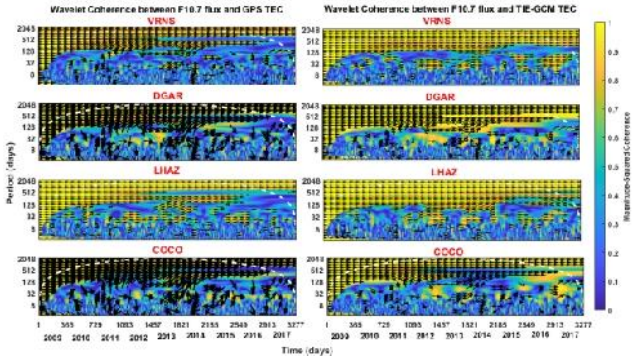

Figure 13. The wavelet coherence spectrum between annually averaged F10.7 flux and GPS TEC (left panel) time series and between annually averaged F10.7 flux and TIE-GCM TEC (right panel) time series is presented. The data used in this figure are 365-days-smoothed-running mean.

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(Sardar Singh Rao, Dibyendu Chakrabarty, and Nandita Srivastava)

Space and Atmospheric Sciences

Characteristics of VOC composition at urban and suburban sites of New Delhi, India in winter

Simultaneous measurements of volatile organic compounds (VOCs) using two PTR-TOF-MS instruments were conducted at urban and suburban sites of New Delhi during the winter of 2018. The time series of VOC mixing ratios show substantial variations mainly influenced by local emissions and meteorological conditions. Mixing ratios of methanol (∼28 ppbv), acetaldehyde (7.7 ppbv), acetone (10.6 ppbv), isoprene (2.8 ppbv) and monoterpenes (0.84 ppbv) at suburban site were higher than those at urban site, while levels of aromatic VOCs were almost similar. The strong nighttime correlations of isoprene and monoterpenes with CO and benzene at urban site indicate their predominant anthropogenic origin. Higher emission ratios of ΔVOCs/ΔCO and ΔVOCs/Δbenzene than those reported for vehicular exhaust suggest the contributions of other sources. In addition to vehicular emissions, episodes of biomass burning, industrial plumes and aged air strongly influenced the levels of VOCs at suburban sites. Despite the predominant primary anthropogenic emissions, the higher daytime enhancements of OVOCs/CO ratios indicate additional contributions of OVOCs from secondary/biogenic sources (Figure 1).

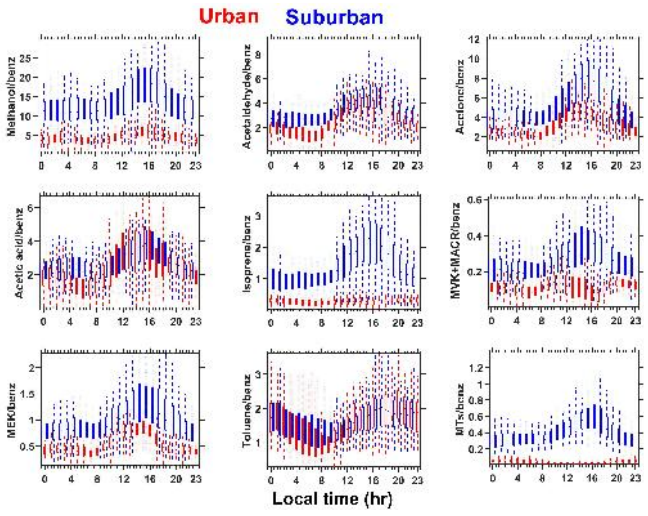

Figure no.1: The box-whisker plots showing the diurnal variation of VOC/benzene ratios (ppb ppb-1) at the urban and suburban sites in New Delhi during the measurement period. In the denominator "benz" stand for benzene.

The secondary formation of OVOCs in moderately aged air masses was noticeable at suburban site. Using the source-tracer-ratio method, the estimated biogenic contributions of isoprene (71%) and acetone (65%) during daytime at suburban site were significantly higher than those for urban site. The photochemical box model simulations suggest that daytime ozone formation was under the VOC-limited regime. This study highlights the impact of different emission sources, photochemical processes and meteorological conditions in the ambient concentration and composition of VOCs in the Delhi region.

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This work is done in collaboration with Sachchida N. Tripathi from Indian Institute of Technology Kanpur & Andr S. H. Prvt from Paul Scherrer Institute, Switzerland and Dilip Ganguly from Indian Institute of Technology Delhi.

(Nidhi Tripathi, L. K. Sahu, Meghna Soni, Kashyap Patel, Neeraj Rastogi, Narendra Ojha)

Real-time measurements of NMVOCs in the central IGB, Lucknow, India: Source characterization and their role in O_3 and SOA formation

Lucknow is the capital of India's largest state, Uttar Pradesh, one of South Asia's most polluted urban cities. Tropospheric photochemistry relies on non-methane volatile organic compounds (NMVOCs), which are ozone and secondary organic aerosol precursors. Using the proton-transfer reaction time of flight mass spectrometer (PTR-ToF-MS) at an urban background site in Lucknow, the chemical characterisation of NMVOCs was performed in real-time from Dec-2020 - May 2021. The campaign mean concentrations of the NMVOCs were 125.5 $\pm$ 37.5 ppbv. The average concentrations of NMVOCs are relatively high during winter. An advanced multi-linear engine (ME-2) model was used to perform the NMVOCs source apportionment using positive matrix factorisation (PMF). It resolves the five main sources contributing to these organic compounds in the atmosphere. They include traffic, two solid fuel combustion factors, secondary volatile organic compounds and volatile chemical products. Biomass burning contributes most to the NMVOCs and SOA formation, while interestingly, traffic sources most influence ozone formation. Significant differences in the composition of the two solid fuel combustion indicate the influence of local emissions and transport of regional pollution to the city. The high temperature during summer leads to more volatilisation of oxygenated VOCs.

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This work is done in collaboration with V. Jain and Sachchida N. Tripathi from Indian Institute of Technology Kanpur & Andr S. H. Prvt from Paul Scherrer Institute, Switzerland and Dilip Ganguly from Indian Institute of Technology Delhi.

(Nidhi Tripathi, Mansi Gupta, and Lokesh K. Sahu)

Trends in sulfur dioxide over the Indian subcontinent during 2003-2019

Sulfur dioxide (SO_2) and its oxidation products have significant influences on air quality and climate. Nevertheless, the long-term trends in SO_2 have been unclear over the rapidly developing Indian subcontinent. In this study, SO_2 trends have been analyzed over the Indian region combining the observations, model results, and satellite datasets during 2003-2019 period. Copernicus Atmosphere Monitoring Service (CAMS) reanalysis shows rapid SO_2 growth up to 0.4 ppbv yr-1 during 2003-2009, particularly over the Indo-Gangetic Plain (IGP) and eastern India (Figure 2). However, the growth becomes slower after 2010 and is followed by stabilization or slight reduction. This result agrees with the satellite-based observations, however, the model underestimates enhancements seen over eastern India. The emission inventories also suggest a slower growth in the SO_2 emissions and coal-fired electricity generation during the recent years. Besides the changes in emissions, the enhancements in water vapor and OH radical coincide with SO_2 stabilization, which suggests strengthening of the sink processes. Model simulation with constant emissions (Modern-Era Retrospective analysis for Research and Applications version 2MERRA-2) shows reduction in SO_2 which confirms the stronger chemical losses. Overall, the SO_2 trends over India are a manifestation of the combined effects of the regional emission change and chemistry. The findings highlight a need to study the impacts of changing SO_2 trends in India on the regional and global climate.

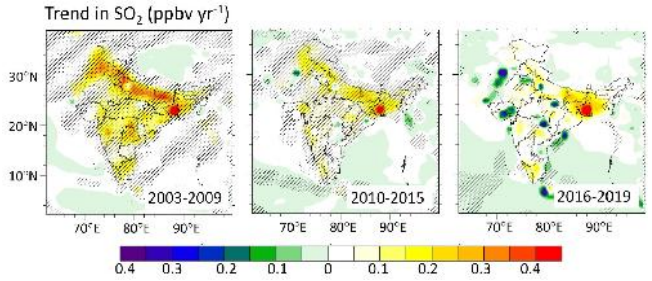

Figure no.2: SO_2 trends over the Indian subcontinent during different periods, derived from CAMS reanalysis. Black shaded lines highlight statistically significant trends.

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This work is done in collaboration with L. Chutia, B. Pathak, P. Bhuyan of Dibrugarh University, I. Girach of SPL VSSC, C. Sarangi of IIT Madras, J. Flemming of ECMWF UK, and A. da Silva of NASA GSFC.

(Narendra Ojha and Lokesh Kumar Sahu)

Relation between PM2.5 and O_3 over Different Urban Environmental Regimes in India

Atmospheric ozone (O_3) concentration is impacted by a number of factors, such as the amount of solar radiation, the composition of nitrogen oxides (NOx) and hydrocarbons, the transport of pollutants and the amount of particulate matter in the atmosphere. In turn, the formation of secondary organic aerosols (SOAs) as a result of atmospheric oxidation are influenced by the prevalent O_3 concentration. We investigated the relationship between PM2.5 (particulate matter smaller than 2.5 micron diameter) and O_3 in different urban environmental regimes of India during the summer and winter seasons. An interesting finding was that during winter PM2.5 and O_3 are negative for Delhi and Bengaluru, but are positively correlated over Ahmedabad. During summer, they are positively correlated over Bengaluru but no significant correlation between them was found over Delhi and Ahmedabad. Analysing meteorological parameters, it was found that negative correlation in winter over Delhi is due to reduction in solar radiation by PM2.5 particles reducing photochemical production of O_3. Over Bengaluru, positive correlation between PM2.5 and O_3 is possibly due to production of SOAs because of humid air. Simultaneous increase in O_3 and PM2.5 over Bengaluru were more common when airmasses where from Arabian Sea compared to when airmasses were from Bay of Bengal.

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This work was done in collaboration with Dr. Chinmay Malik of Department of Atmospheric Science, Central University of Rajasthan, Ajmer 305801, India and others.

(Harish Gadhavi, Akanksha Arora and Shyam Lal)

Trends in columnar aerosol characteristics and radiative effects over South and East Asia

Recent satellite observations of atmospheric aerosol loading over Asia indicate a dipole pattern in the aerosol optical depth (AOD) with a substantial decrease in AOD over East Asia and persistent increase in AOD over South Asia, the two global hotspots of aerosol emissions (Figure 3). The aerosol emissions over Asia are also changing rapidly. However, the evolution of physical, optical and chemical columnar aerosol characteristics, and their radiative effects over time, and the resultant impacts of such evolving trends on climate and other associated risks are not yet properly quantified, and used in climate impact assessments. We have closely examined, in addition to satellite observations, for the first time, high-quality, two-decade long ground-based observations since 2001 of aerosol characteristics and their radiative effects (18 parameters) from several locations (7) in the Indo-Gangetic Plain (IGP) in South Asia and the North China Plain (NCP) in East Asia (Figure 3). A clear divergence in the trends in AODs is evident between the IGP (Kanpur) (Figure 4) and the NCP (Beijing) (Figure 5). The single scattering albedo (SSA) is increasing, and the absorption AOD due to carbonaceous aerosols ($AAOD_{CA}$) is decreasing over both the regions, confirming that aerosols are becoming more scattering in nature (Figures 4, 5). The trends in observed aerosol content (AOD) and composition (SSA) are statistically significant over Kanpur in the IGP and Beijing in the NCP, two locations with longest records (Figures 4, 5). The aerosol radiative forcing of the atmosphere (ARF_{ATM}) and resultant atmospheric heating rate (AHR) are decreasing over both the regions (Figures 4, 5). However, current regionally coherent and high annual AHR of 0.5-1.0 K day^{-1} (Figures 4, 5) has severe implications to climate, hydrological cycle, and cryosphere over Asia and beyond. These results based on high-quality observations over a large spatial domain are of great significance and are crucial for modelling and quantifying aerosol-climate interactions.

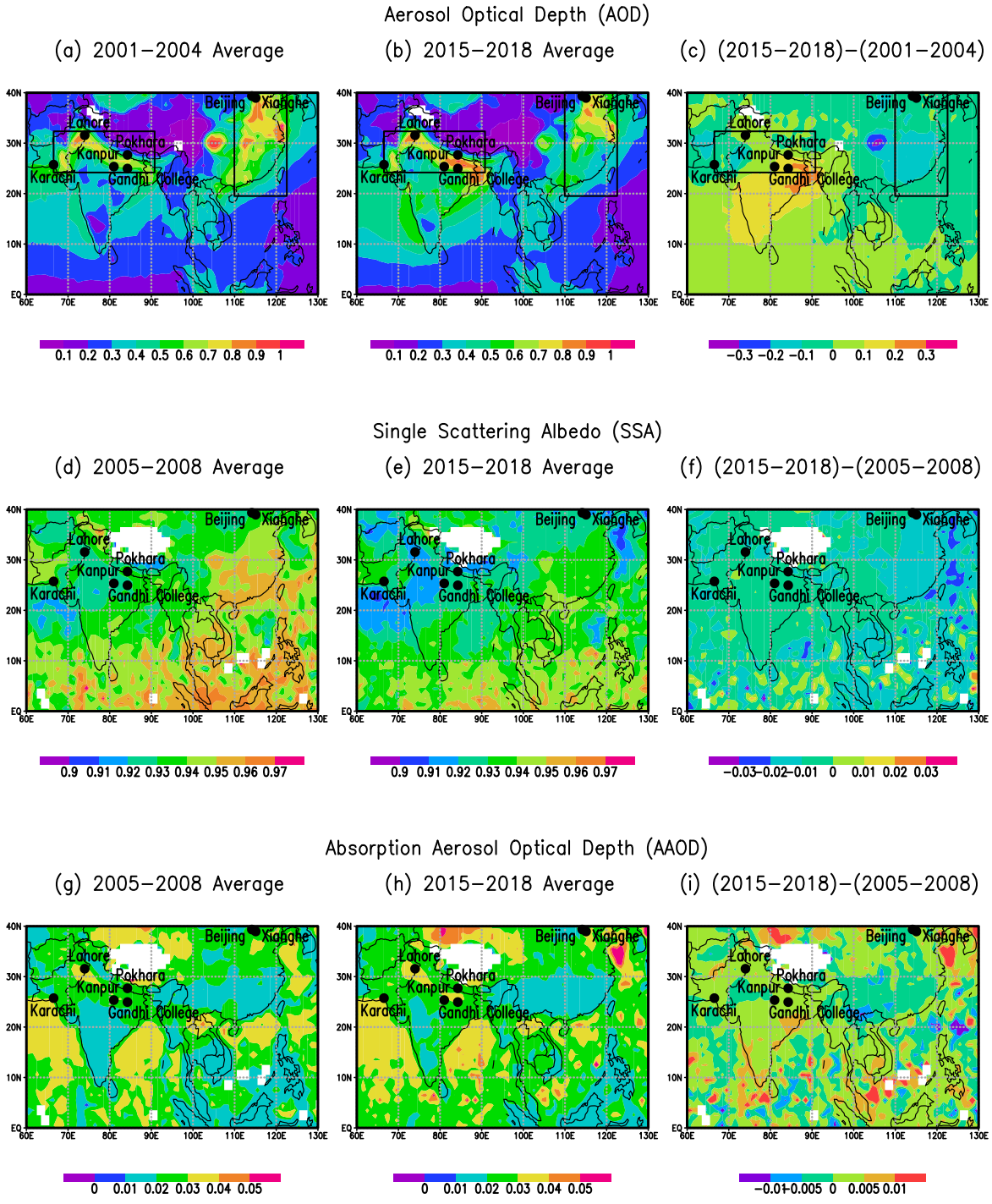

Figure no.3: Satellite observations of changing aerosol patterns over Asia. Moderate Resolution Imaging Spectroradiometer (MODIS) Terra aerosol optical depth (AOD) (a) average for 2001-2004 and (b) average for 2015-2018, and (c) the difference between 2015-2018 average and 2001-2004 average. Ozone Monitoring Instrument (OMI) retrieved daily single scattering albedo (SSA) (d) average for 2005-2008 and (d) the average for 2015-2018, and (f) the difference between (e) and (d). OMI retrieved absorption AOD (AAOD) (g) average for 2005-2008, (f) average for 2015-2018 and (i) the spatial difference between 2015-2018 average and 2005-2008 average. All the study locations in South and East Asia are marked in the figure.

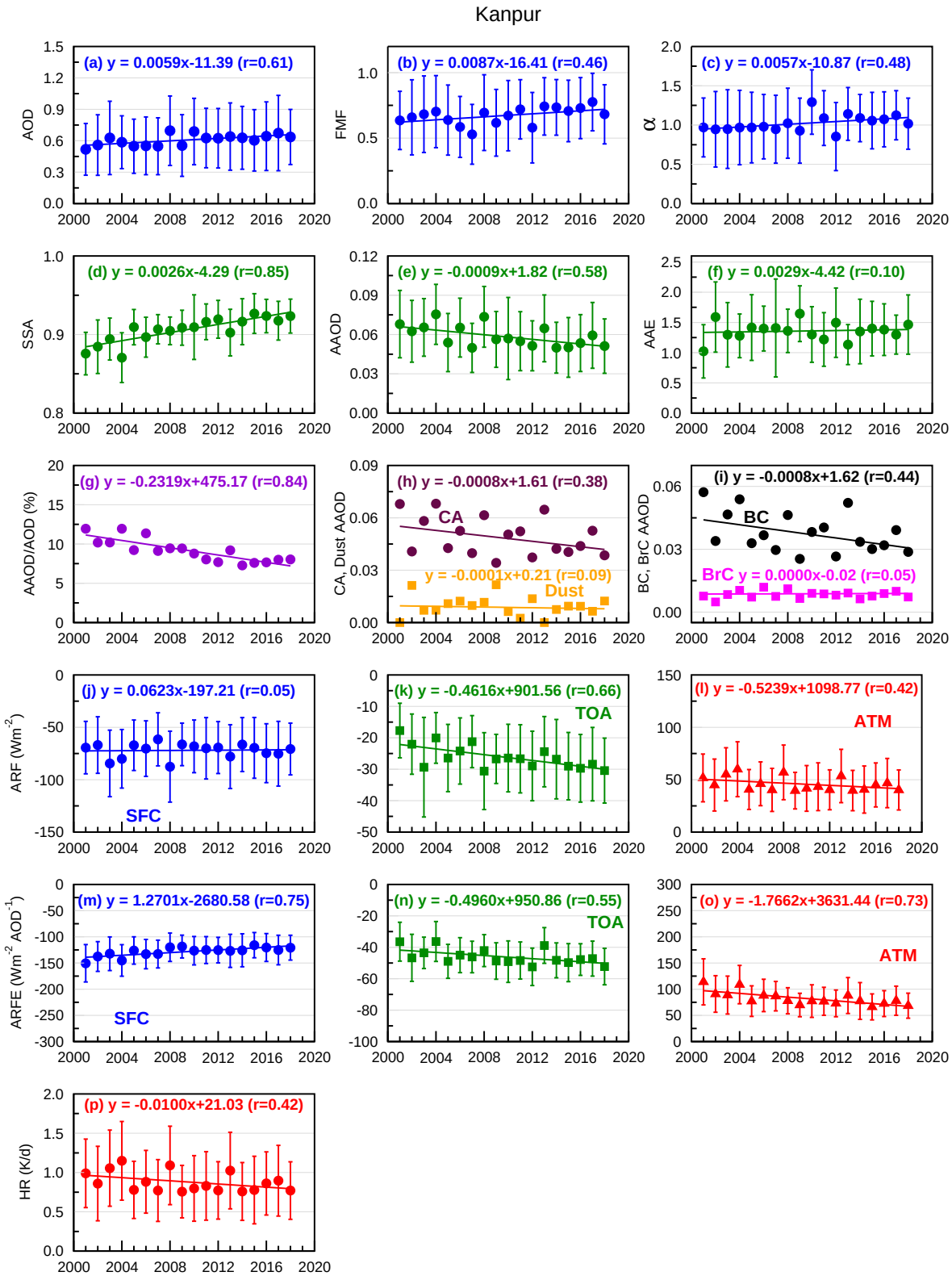

Figure no.4: Aerosol characteristics and radiative forcing over Kanpur in the Indo-Gangetic Plain (IGP) based on the AERONET measurements during 2001-2018. Trends in (a) AOD, (b) FMF, (c) α, (d) SSA, (e) AAOD, (f) AAE, (g) AAOD/AOD (%), (h) $AAOD_{CA}$ and $AAOD_{Dust}$, (i) $AAOD_{BC}$ and $AAOD_{BrC}$, (j) ARF_{SFC}, (k) ARF_{TOA}, (l) ARF_{ATM}, (m) $ARFE_{SFC}$, (n) $ARFE_{TOA}$, (o) $ARFE_{ATM}$ and (p) AHR. Vertical bars indicate $\pm 1\sigma$ standard deviation from the annual mean.

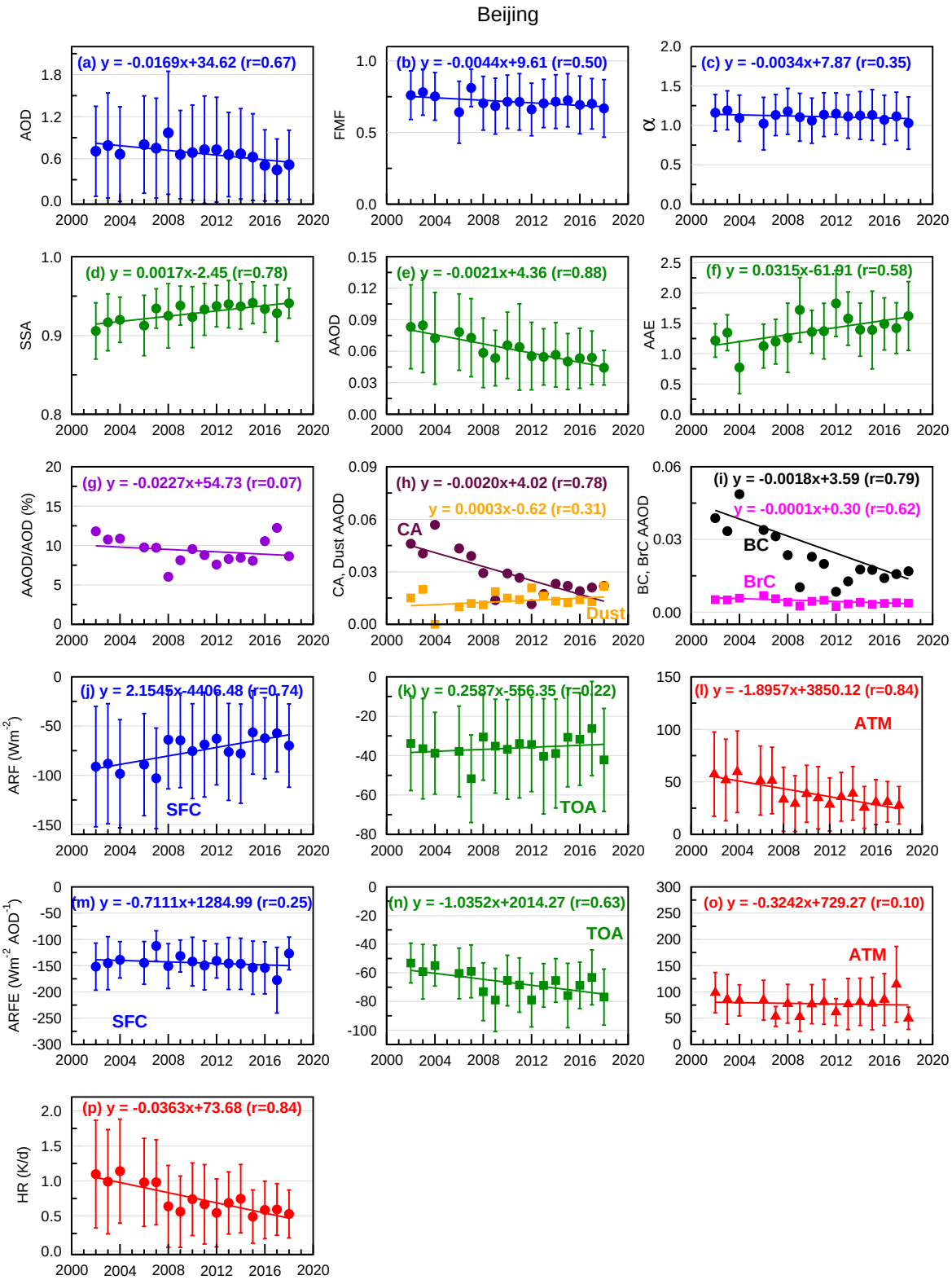

Figure no.5: Aerosol characteristics and radiative forcing over Beijing in the North China Plain (NCP) based on the AERONET measurements during 2001-2018. Trends in (a) AOD, (b) FMF, (c) α, (d) SSA, (e) AAOD, (f) AAE, (g) AAOD/AOD (%), (h) $AAOD_{CA}$ and $AAOD_{Dust}$, (i) $AAOD_{BC}$ and $AAOD_{BrC}$, (j) ARF_{SFC}, (k) ARF_{TOA}, (l) ARF_{ATM}, (m) $ARFE_{SFC}$, (n) $ARFE_{TOA}$, (o) $ARFE_{ATM}$ and (p) AHR. Vertical bars represent $\pm 1\sigma$ standard deviation from the annual mean.

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This work was done in collaboration with Maheswar Rupakheti, Institute for Advanced Sustainability Studies, Potsdam, Germany.

(S. Ramachandran)

Climatology and trends in aerosol types and absorption characteristics of ambient aerosols over the Indo-Gangetic Plain and North China Plain

Climatology and trends in different types of aerosols with focus on absorbing aerosols over Kanpur located in IGP in South Asia and Beijing in NCP in East Asia are investigated.

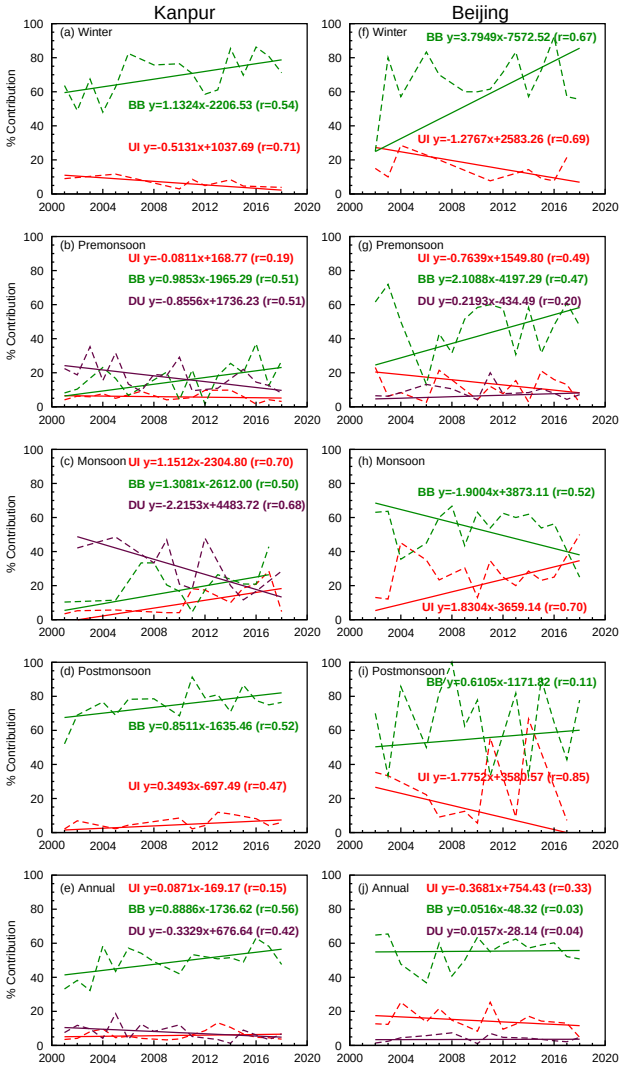

Figure no.6: Seasonal and annual trends in aerosol types [urban/industrial (UI), biomass burning (BB) and dust (DU)] derived from the AERONET observations over Kanpur and Beijing during(2001-2018): Left column for Kanpur [(a) winter, (b) pre-monsoon, (c) monsoon, (d) post-monsoon, and (e) annual], and right column for Beijing [(f) winter, (g) pre-monsoon, (h) monsoon, (i) post-monsoon, and (j) annual]. The equations for the overall trend (2001-2018) for each aerosol type are given in each figure.

A first analysis of high-quality time series of columnar aerosols observations over a period of nearly two-decades, along with satellite observations was performed to provide a broader regional perspective. Satellite retrieved aerosol Ångström exponent (AE) values have increased (10-20%) suggesting an increasing contribution of fine mode aerosols (<1 μm in radius) to aerosol optical depth (AOD) over Asia in the last 2-decades. Among the three aerosol types [urban-industrial (UI), biomass burning (BB), and dust (DU)], only UI and BB aerosols are present over Kanpur throughout the year, while DU is present along with UI and BB aerosols only during pre-monsoon and monsoon. Overall, there is a positive trend in BB aerosols over both Kanpur and Beijing, a positive (negative) trend in UI aerosols over Kanpur (Beijing), and positive (negative) trend in dust over Beijing (Kanpur) (Figure 6). Positive trend in BB aerosols over Kanpur is statistically significant.

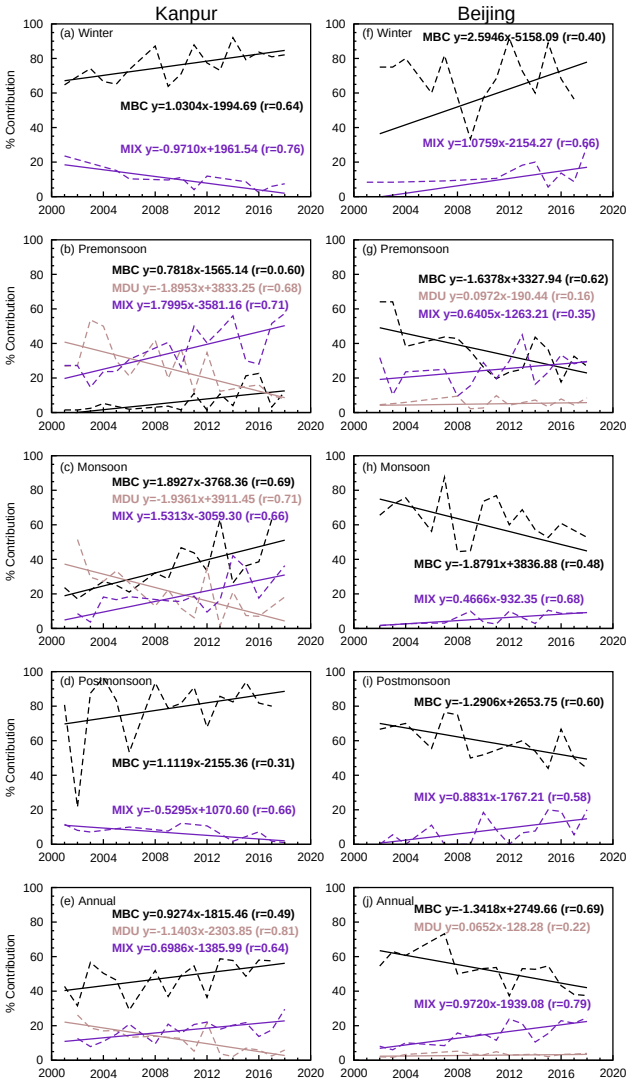

Figure no.7: Seasonal and annual trends in absorbing aerosol types [classified as Mostly BC (MBC), Mostly Dust (MDU), and Mixed (MIX)] over the IGP and NCP during (2001-2018): left column for Kanpur [(a) winter, (b) pre-monsoon, (c) monsoon, (d) post-monsoon, and (e) annual], and right column for Beijing [(f) winter, (g) pre-monsoon, (h) monsoon and (i) post-monsoon, and (j) annual]. Trend lines and the equations for the overall trend (2001-2018) for the respective absorbing aerosol type are given in each figure.

Among three absorbing aerosol types [mostly black carbon (MBC), mostly dust (MDU), and mixed (MIX) containing BC and dust], only MBC and MIX are present in post-monsoon and winter over IGP, and MDU is present along with MBC and MIX only during pre-monsoon and monsoon, in agreement with aerosol types found. Trends in MBC, MIX and MDU over Kanpur in IGP and in MIX over Beijing are statistically significant (Figure 7). These trends are attributed mainly to changes in anthropogenic aerosol emissions, and not to natural and climatic factors as their changes are relatively small. These findings on hitherto unavailable climatology and trends in aerosol types and absorbing aerosols over two global aerosol hotspots and identified contrasts will be crucial in model simulations to better decipher aerosol-climate interactions over Asia.

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This work was done in collaboration with Maheswar Rupakheti, Institute for Advanced Sustainability Studies, Potsdam, Germany.

(S. Ramachandran)

Assessment of the coronavirus disease 2019 (COVID-19) pandemic imposed lockdown and unlock effects on black carbon aerosol, its source apportionment, and aerosol radiative forcing

A nationwide lockdown was imposed across India due to the Coronavirus Disease 2019 (COVID-19) pandemic which significantly reduced anthropogenic emissions.

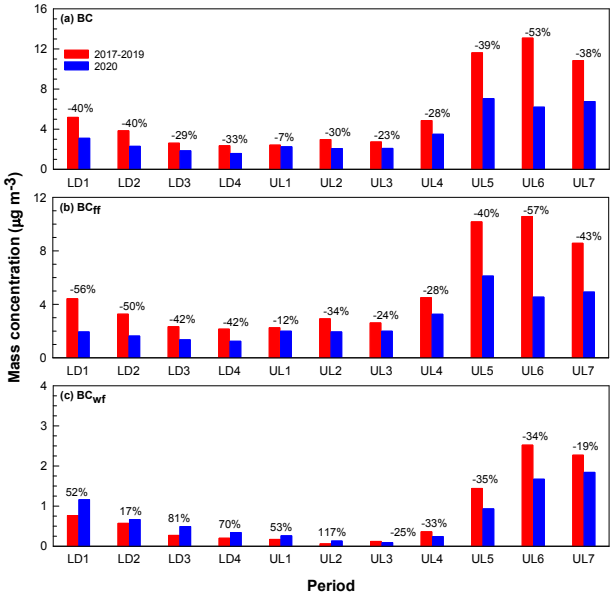

Figure no.8: Variation of black carbon (BC), fossil fuel (BC_{ff}) and wood fuel (BC_{wf}) mass concentration over Ahmedabad during the study phases (LD1, LD2, LD3, LD4, UL1, UL2, UL3, UL4, UL5, UL6, and UL7) of (2017-2019) and 2020. The numbers (%) in each figure correspond to the anomalies in percentage for different lockdown and unlock phases. The anomalies are calculated as ((BC in 2020 - mean BC during 2017-2019)/mean BC during (2017-2019) 100.

We investigated the characteristics of black carbon (BC) mass concentration and its source apportionment using a multi-wavelength aethalometer over an urban site (Ahmedabad) during the pandemic induced lockdown period of year 2020. For the first time, the changes in BC, its contribution from fossil (BC_{ff}) and wood (BC_{wf}) fuels during lockdown (LD) and unlock (UL) periods in 2020 with respect to 2017 to 2019 (normal period) are estimated. BC mass concentration continuously decreased throughout lockdown periods (LD1 to LD4) due to enforced and stringent restrictions which substantially reduced the anthropogenic emissions (Figure 8). BC mass concentration increased gradually during unlock phases (UL1 to UL7) due to phase wise relaxations after lockdown. During the lockdown period BC mass concentration decreased by 35%, whereas during the unlock period BC decreased by 30% as compared to normal period. The BC_{wf} concentrations were higher by 40% during lockdown period than normal period due to significant increase in the biomass burning emissions from the several community kitchens which were operational in the city during the lockdown period. The average contributions of eBC_{ff} and eBC_{wf} to total BC mass concentrations were 70% and 30% respectively during lockdown (LD1 to LD4) period, whereas these values were 87% and 13% respectively during the normal period. The reductions in BC concentrations were commensurate with the reductions in emissions from transportation and industrial activities. The aerosol radiative forcing of the atmosphere reduced significantly due to the reduction in anthropogenic emissions during the lockdown leading to a cooling of the atmosphere. The findings can provide a comprehensive understanding of the BC sources and current emission control strategies, and thus, can serve as baseline anthropogenic emissions scenario for future emission control strategies aimed to improve air quality and climate.

doi : https://doi.org/10.1016/j.atmosres.2021.105924

(T. A. Rajesh and S. Ramachandran)

Aerosol characteristics over Indo-Gangetic Plain from ground-based AERONET observations and MERRA-2/CAMS model simulations

A comprehensive investigation of physical, optical, and chemical columnar characteristics of aerosols over two locations with distinct environmental settings in the Indo-Gangetic Plain (IGP) region, an aerosol hotspot (AOD $>$0.5 throughout the year, Figure 9), namely, Kanpur (urban and industrial area) and Gandhi College (rural area), is conducted using high-quality aerosol datasets obtained from ground-based Aerosol Robotic Network (AERONET) observations during the recent five years (2015-2019). This study utilized all crucial aerosol columnar parameters necessary for accurately estimating aerosol radiative forcing. Quantification of contribution by different aerosol species originating from natural and anthropogenic sources to the total aerosol optical depth (AOD) is important to understand the specific mechanisms that influence aerosol composition, thereby reducing the uncertainty in aerosol radiative forcing. For the first time, the highly spatially resolved model (Modern-Era Retrospective Analysis for Research and Applications-2 (MERRA-2) and Copernicus Atmosphere Monitoring Service (CAMS)) simulated absorbing species-wise (black carbon (BC), dust, and brown carbon (BrC)) AOD and absorption AOD (AAOD) are compared and contrasted against AERONET observations over the IGP region. AOD at 0.50 μm ($AOD_{0.50}$), Ångström exponent ($AE_{0.44-0.87}$) and fine mode fraction (FMF) over Kanpur and Gandhi College exhibit a strong seasonal variation (Figure 10).

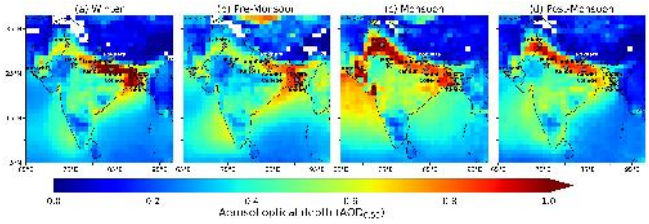

Figure no.9: Seasonal mean variation of MODIS retrieved aerosol optical depth at 0.55 μm wavelength ($AOD_{0.55}$) over the Indian subcontinent during (a) winter (DJF), (b) pre-monsoon (MAM), (c) monsoon (JJAS), and (d) post-monsoon (ON) averaged for the years (2015-2019). The study locations, Kanpur and Gandhi College, are shown in the map.

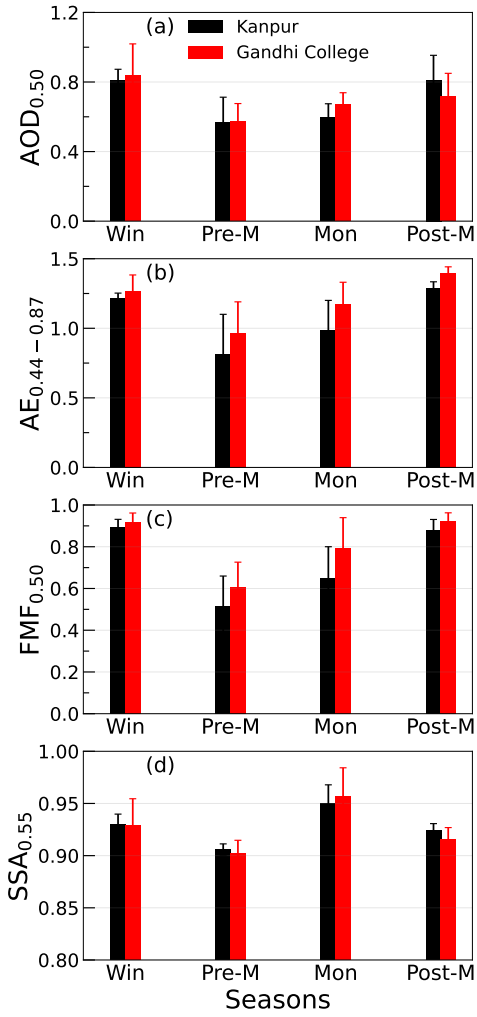

Figure no.10: Seasonal variation of (a) aerosol optical depth ($AOD_{0.55}$), (b) Ångström exponent ($AE_{0.44-0.87}$), and (c) fine mode fraction ($FMF_{0.50}$) and single scattering albedo ($SSA_{0.55}$) along with $\pm 1\sigma$ standard deviation from their respective seasonal mean over Kanpur and Gandhi College.

MERRA-2 AODs are mostly lower, whereas CAMS AODs are consistently higher than AERONET AODs (Figure 11). Comparison of collocated time and space observations with models clearly suggests improvements in emission inventories on seasonal scales are essential. MERRA-2 single scattering albedo (SSA) is notably lower than AERONET SSA during the winter season due to overestimation in BC AOD (Figure 12). Both models show a gradient in AOD_{Dust} decreasing from west to east in the IGP. However, observations do not often exhibit the gradient in dust, which is validated by air mass back trajectory analyses as air masses travel through different pathways to IGP and reverse the west to east gradient in AOD_{Dust}. This quantitative and comparative collocated analysis of observed aerosol characteristics with models on a seasonal scale will enable a better estimation of aerosol radiative forcing and can help improve aerosol processes and parameterizations in models.

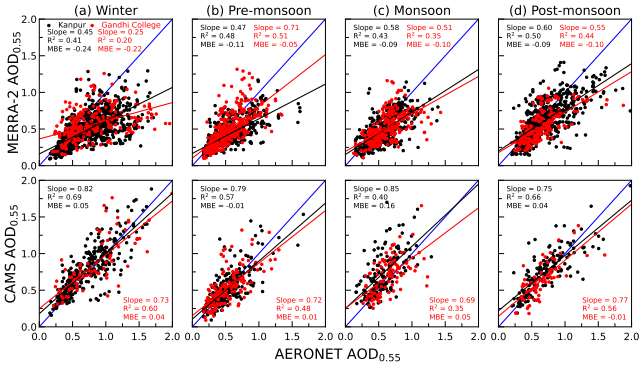

Figure no.11: Comparison of collocated AERONET measurements with MERRA-2 (1-hour) and CAMS (3-hour) simulated $AOD_{0.55}$ over Kanpur (black) and Gandhi College (red) during (a) winter, (b) pre-monsoon, (c) monsoon and (d) post-monsoon seasons of 2015-2016. The values of slope, coefficient of determination (R^2) of fitted linear line and mean bias error (MBE: mean difference between AERONET and the respective model) are shown in each panel. Solid blue line corresponds to 1:1 ratio.

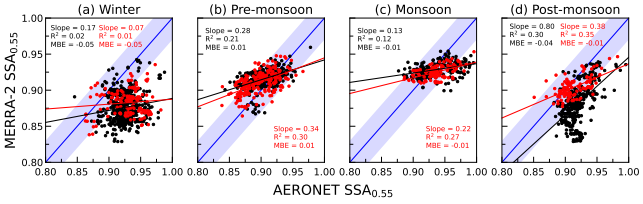

Figure no.12: Comparison of AERONET observed $SSA_{0.55}$ with collocated hourly MERRA-2 simulated $SSA_{0.55}$ over Kanpur (black) and Gandhi College (red) during (a) winter, (b) pre-monsoon, (c) monsoon and (d) post-monsoon seasons of 2015-2016. Blue shaded region denotes the uncertainty range in AERONET SSA (± 0.03) and the solid blue line corresponds to 1:1 ratio. Slope, R^2 of fitted linear line and MBE (mean difference between AERONET and MERRA-2 model) are given in each panel.

doi : https://doi.org/10.1016/j.atmosenv.2022.119434

(Kamran Ansari and S. Ramachandran)

Radiative effects of absorbing aerosol types over South Asia

A comprehensive study on classifying the aerosol types and absorbing aerosol types, and quantifying the effect of absorbing aerosols on aerosol optical and radiative properties using four years (2015-2016, 2018-2019) high-quality datasets over Kanpur (urban) and Gandhi College (rural) in Indo-Gangetic Plain (IGP) region is conducted on a seasonal scale, for the first time. Biomass burning (BB), urban-industrial, and mixed aerosol types are always present,

whereas dust aerosol and mostly dust (MD) absorbing aerosol types are only present in pre-monsoon and monsoon seasons over the IGP. During winter and post-monsoon seasons, BB aerosols and mostly black carbon (MBC) absorbing aerosols dominate, and the contribution of aerosol optical depth (AOD) and single scattering albedo (SSA) corresponding to MBC to total AOD and SSA are higher (Figure 13).

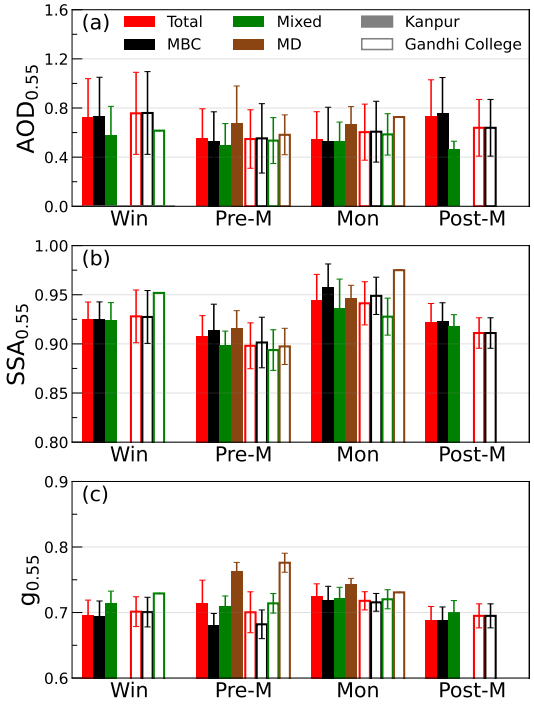

Figure no.13: The seasonal variation of (a) AOD, (b) SSA, and (c) asymmetry parameter (g) at 0.55 μm for absorbing aerosol types (mostly black carbon (MBC), mixed (BC + dust), and mostly dust (MD)) and total containing all absorbing aerosol types over Kanpur and Gandhi College. The vertical bars represent $\pm 1\sigma$ (standard deviation) from the seasonal mean.

SSA for MBC varies over a broader range due to mixing of BC with water-soluble aerosols. During pre-monsoon and monsoon seasons, mixing of dust with anthropogenic aerosols increases the amount of mixed aerosol type. Surface cooling and atmospheric heating efficiency for mixed aerosols are higher than MBC and dust aerosols due to enhancement in aerosol absorption over both locations. Seasonal analysis of aerosol radiative properties showed that during winter and post-monsoon, MBC absorbing aerosols are the major contributor in controlling/influencing the total aerosol radiative forcing (ARF) and heating rate (HR) (Figure 14). During the other seasons, each absorbing aerosol type significantly influences ARF depending on their AOD and SSA values. In a regional-scale examination of ARF, annual mean atmospheric ARF (ARF_{ATM}) and ARF efficiency ($ARFE_{ATM}$), and HR are higher for MBC, followed by mixed and MD aerosols over South Asia due to higher AOD and absorbing efficiency of MBC aerosols (Figure 15). In comparison over East Asia, mixed aerosols exhibit higher ARFATM. This quantification of absorbing aerosol types over a global aerosol hotspot will be useful for accurate quantification of climate impacts of aerosols.

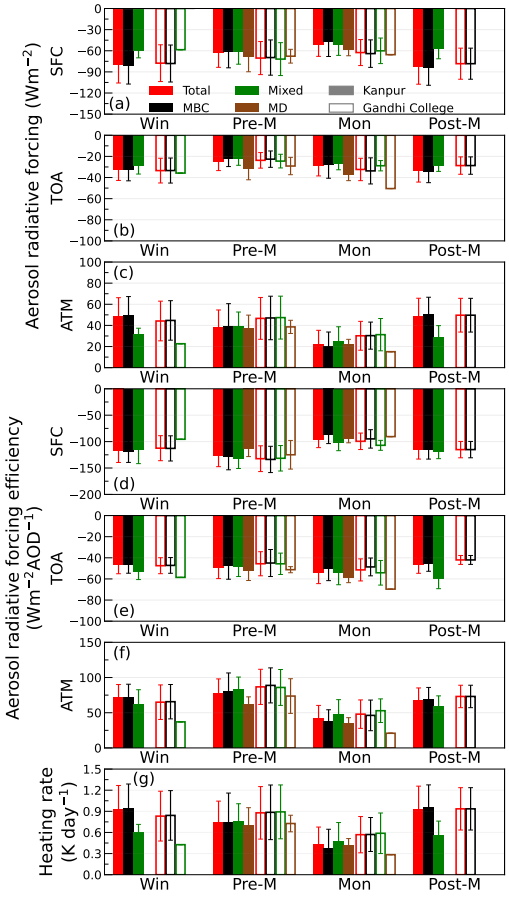

Figure no.14: Seasonal variation in direct ARF at the (a) surface (SFC), (b) top of the atmosphere (TOA), and (c) in the atmosphere (ATM), ARF efficiency (ARFE) at (d) SFC, (e) TOA, and in (f) ATM, and (g) heating rate (HR) for absorbing aerosol types (MBC, mixed, and MD) and total containing all absorbing aerosol types over Kanpur and Gandhi College corresponding. Vertical bars indicate $\pm 1\sigma$ (standard deviation) from the seasonal mean.

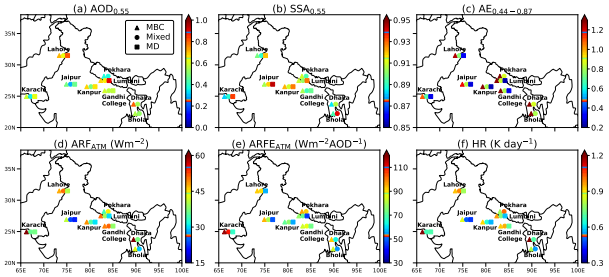

Figure no.15: The regional distribution of annual mean (a) aerosol optical depth (AOD), (b) single scattering albedo (SSA), (c) Ångström exponent (AE), (d) aerosol radiative forcing in atmosphere (ARF_{ATM}), (e) ARF efficiency in atmosphere ($ARFE_{ATM}$), and (f) heating rate (HR) for absorbing aerosol types (mostly BC (MBC): ▲, mixed (BC + dust): ●, and mostly dust (MD): ■) over the South Asian region. Color of the symbol represents the magnitude of the respective aerosol parameter according to the color scale in each panel.

doi : https://dx.doi.org/10.1016/j.scitotenv.2022.159969

(Kamran Ansari and S. Ramachandran)

Atmospheric Boundary Layer Over Ahmedabad, Western Indian Region: Impact of COVID-19 Nationwide Lockdown

The Atmospheric Boundary Layer (ABL) is the lowermost layer of the atmosphere in contact with the Earths surface. ABL is very crucial as it helps in the exchange of heat and momentum from the surface to the free atmosphere and vice versa, and helps in vertical mixing of the near-surface pollutants. The Government of India imposed a nation-wide lockdown to tackle the outbreak of COVID-19 in 2020. This period witnessed record low anthropogenic activities which had severe socio-economic impacts but had orthogonal effects on the ambient air quality of the atmosphere. This study focuses on the variations of Atmospheric Boundary Layer (ABL) over the western Indian urban region in the light of Covid-19. Continuous backscatter recorded by Ceilometer, stationed at Ahmedabad, have been used in this study to monitor the ABL during the national lockdown (NLD) in 2020, state restrictions in 2021 and compared with control year: 2019. Parallelly, improvement in air quality during NLD has been observed by the SAFAR Air Quality Station at Ahmedabad with decreasing particulate matter concentrations. The ground-based observations have been substantiated by ERA-5 reanalysis dataset. A decline in the ABL height has been recorded during NLD, which showed improvement in 2021 but shy of the ABL in 2019. This has been correlated with rain events during the observational period, recorded by Automatic Weather Station.

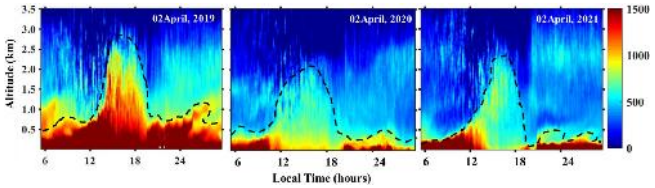

Figure no.16: Comparison of range time intensity plot of backscatter received on a rain-free day by Ceilometer, stationed at PRL during 2019, 2020 and 2021. The black dotted line shows the boundary layer height throughout the day. Here April 2 has been chosen as a representative day for the comparison of the event and control years.

doi : https://doi.org/10.1007/s00024-023-03230-0

This work was done in collaboration with Kondapalli Niranjan Kumar (NCMRWF, MoES, Delhi) and Prashant Kumar and Abha Chhabra (SAC, ISRO).

(Sourita Saha, Som Sharma, Dharmendra Kamat, and Shyam Lal)

The behavior of cloud base height over a hilly remote station of North-East India using ground-based remote sensing technique

Impact of clouds and their vertical structures on the radiative budget, hydrological cycle, and climate is strong but still uncertain. There is a need to monitor and investigate cloud characteristics continuously to improve our knowledge and understanding. The behavior of the Cloud Base Height (CBH) is studied over Umiam, situated in a complex terrain of the Shillong Plateau. CBH measurements are obtained from a LIDAR Ceilometer and a comprehensive analysis of its characteristics covering from February 2019 to January 2022 has been presented here. Cloud occurrences showed distinct seasonality with maxima in wet months and minima in dry months. Multilayer cloud structures are found mostly in the monsoon season, although single-layer clouds dominate throughout the year. During the whole study period, the average frequency of occurrences of single, double, and triple layers of clouds are found at 38.5%, 11%, and 0.01% respectively against a total observation point of 78%. Near-ground cloud occurrences are ubiquitous with a maximum in July 2020 (18.08%) and a minimum in April 2021 (0.03%). CBH is found to vary with seasons too with higher bases during pre-monsoon months and lower during monsoon and post-monsoon months. Nighttime and early morning maxima in cloud occurrences are noted in some seasons. Cloud formation and occurrences are found to follow a pattern of existing circulation, dominated by local circulation during post-monsoon and winter and synoptic circulation during pre-monsoon and monsoon seasons. A comparison study of CBH with corresponding reanalysis datasets showed their inability to capture cloud representation over sloped terrain.

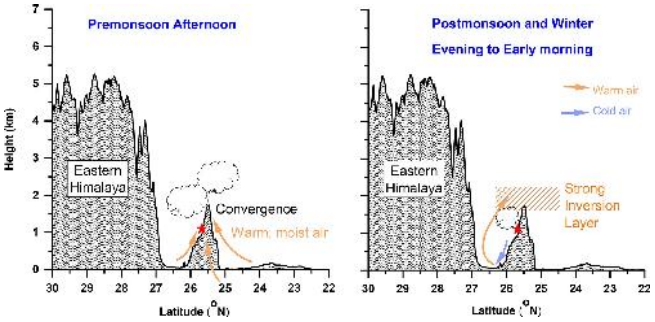

Figure no.17: Typical features f cloud formation observed in different seasons due to variations in circulations.

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This work was done in collaboration with Arundhati Kundu, Shyam S. Kundu, Manasi Gogoi, Arup Borgohain, Anjan Debnath (NESAC, Umiam, Meghalaya, India) and Rahul Mahanta (Cotton University, Assam) and Trisanu Banik (IMD, New Delhi).

(Som Sharma)

Investigation on the MLT tidal variability during September 2019 minor sudden stratospheric warming

Tidal variability in the mesosphere and lower thermosphere (MLT) during September 2019 Southern hemisphere minor sudden stratospheric warming (SSW) is investigated utilizing ground-based meteor radar wind observations from the equatorial, extratropical, middle, and high latitude stations and global reanalysis dataset. The polar warming is found to move from the mesosphere to the stratosphere until the peak warming day (PWD) of the SSW. The diurnal and semidiurnal tides at individual observational sites do not exhibit any consistent response during the observational interval, but a notable and consistent variability in some specific zonal wavenumber components, i. e., DW1 (migrating diurnal tide), DE3 (nonmigrating eastward wavenumber 3 diurnal tide), and SW2 (migrating semidiurnal tide) is found in the global reanalysis dataset. Incidentally, the warming event occurs during Spring equinox when a dominant seasonal

change in the tidal activities generally takes place and hence seasonal variability is also looked into while identifying the SSW impact during the observational interval. It is found that the seasonal broad changes in the DW1, DE3, and SW2 amplitudes can be explained by the variability in the tidal sources, i.e., water vapor, convective activity, ozone, etc during the observational period. However, the extracted short-term variability in the global tidal modes on removing seasonal trends reveals a noticeable response in connection with the warming event. The deseasoned amplitude of the DW1 significantly enhances around the PWD at most of the present latitudes. The deseasoned DE3 amplitude response significantly in the middle atmosphere at low latitudes during the warming phase. The deseasoned SW2 exhibit clear enhancement around the PWD at all the latitudes. However, the deseasoned tidal features do not seem to correlate well with that of the source species unlike the seasonal ones that imply involvement of complex processes during the warming event, seeking further future investigations in this regard.

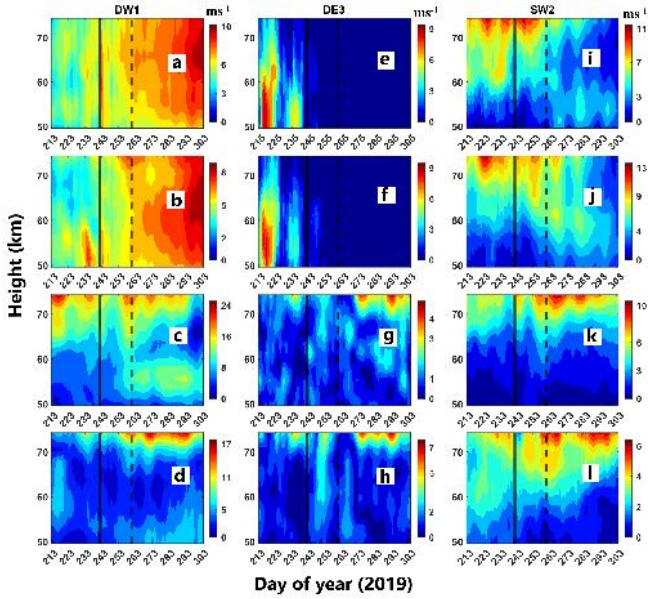

Figure no.18. Temporal variation in the DW1 amplitude in ms^{-1} in the mesosphere (50-75 km altitude) at (a) 67.5° S, (b) 54.5° S, (c) 22.5° S and (d) 7.5° S estimated using meridional wind data from MERRA-2. Same for the DE3 amplitude in ms^{-1} at (e) 67.5° S, (f) 54.5° S, (g) 22.5° S and (h) 7.5° S, and for the SW2 amplitude in ms^{-1} at (i) 67.5° S, (j) 54.5° S, (k) 22.5° S and (l) 7.5° S. Please note the change of scale in the color bars while comparing.

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This research work was done in collaboration with P. P. Batista, National Institute for Space Research, São José dos Campos, São Paulo, Brazil, R. A. Buriti, Federal University of Campina Grande, Campina Grande, Paraiba, Brazil andT. Moffat-Griffin, British Antarctic Survey, Cambridge, UK.

(G. Mitra and A. Guharay)

Distinct ionospheric response to three different geomagnetic storms over the Indian equatorial and low latitude sectors

The ionospheric response during three distinct strong geomagnetic storms that occurred in the year 2016 is investigated using GPS-TEC observations. These three storms are different from one another in the sustenance of the main and recovery phases and occurred at three different local times corresponding to Indian longitudes. Two geomagnetic storms (20 January 2016 and 13 October 2016) occurred at the similar local time (IST) with similar strength have shown different ionospheric responses demonstrated by the relative dominance of penetration electric fields and thermosphere wind disturbances on one another. A faint positive storm effect associated with a short impulsive Northward followed by Southward excursion in an interplanetary magnetic field is observed. Strong positive storm effects during the post-storm period associated with CIR induced thermospheric disturbances are also observed.

doi : https://doi.org/10.1016/j.asr.2022.05.027

This work is done in collaboration with D. Lissa, D.S.V.V.D. Prasad and K. Niranjan of Andhra University, Visakhapatnam.

(K. Venkatesh)

Longitudinal differences in the ionospheric response to the major sudden stratospheric warming event of 2019

A major sudden stratospheric warming (SSW) event occurred during 22 December 2018 to 20 January 2019, wherein the temperature at 90° N increased by 58°K above the historical mean and zonal wind revered from east to west. Longitudinal and latitudinal differences in the ionospheric response to this SSW event is investigated using TEC observations from 88 GPS receivers in the American and African sectors. In the American longitudes, the TEC was enhanced during the SSW peak followed by reduction during the post-peak phase of the SSW. The disturbances in TEC have shown hemispheric asymmetry in the African longitudes. Poleward departure of the EIA crest is noted with stronger crests in the southern hemisphere in both sectors, indicating the possible role of wind disturbances during the SSW.

doi : https://doi.org/10.1016/j.jastp.2022.105945

This work is done in collaboration with F. Vieira, P.R. Fagundes, V.G. Pillat, E. Agyei Yeboah, M.O. Arcanjo of Universidade do Vale do Paraíba (UNIVAP), Brazil.

(K. Venkatesh)

Studies of atmospheric waves by ground-based observations of OH(3-1) emission and rotational temperature using PRL Airglow InfraRed Spectrograph (PAIRS)

Vertical coupling of the atmospheres due to upward propagating waves in the mesosphere lower thermosphere (MLT) region has been investigated using simultaneous measurement of the OH(3-1) brightness and corresponding rotational temperatures. If the common periodicities seen in the brightness and temperature are due to an upward propagating wave, the brightness and temperature fluctuations are related by the Krassovsky parameter. Measurement of rotationally resolved OH(3-1) band nightglow emissions and corresponding rotational temperatures in the 1.5 to 1.6 μm spectral

region at a resolution of 0.001 μm @ 1.532 μm has been initiated using PRL Airglow InfraRed Spectrograph (PAIRS) from Thaltej Campus. The data cadence of PAIRS is 100 seconds providing an opportunity to study small time scale oscillations present at the OH emission altitude. We have carried out a detailed characterization of term diurnal, large- and small-timescale gravity wave (GW) induced oscillations applying Krassovsky's method to nocturnal variations of the OH(3-1) brightness and its rotational temperatures.

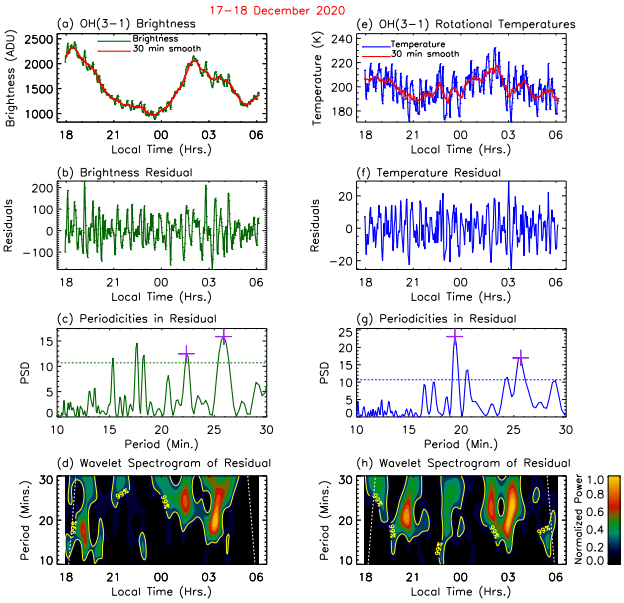

Figure no.19: Short time scale periodicities present in the nightglow emission brightness and its rotational temperatures for the night of 17 December 2020. (a) Observed zenith nocturnal variations in the OH(3-1) brightness (green line) and 30 minutes running averaged data (red line). (b) Residuals in brightness as obtained by subtracting 30-minute running averaged data from the original brightness data. (c) Lomb-Scargle periodograms of the residual in the brightness variations. (d) Wavelet spectrogram of the brightness residuals along with the cone of influence and 99% significant level. (e-h) Similar to Figures (a-d) but for rotational temperatures. We can observe noticeable wave activities in the range of 10 minutes to 30 minutes with occurrences of different periods at different times throughout the night. The coherent periodicities in brightness and temperature that are related by Krassovsky parameters are shown by purple plus sign in Figures 19(c) and 1(g) and are due to GW propagation from the lower to the upper atmosphere.

The wave characteristics e.g., period, amplitudes, phases, Krassovsky parameters, and vertical wavelengths of the terdiurnal tide and GWs are calculated using a least square fitting and wavelet analysis techniques. We also demonstrate capabilities of PAIRS in estimating the characteristics of GWs with periodicities smaller than 30 minutes, which showed upward wave propagation. PAIRS provides for the first time measurement of rotational temperatures using high cadence OH(3-1) infrared band spectra from India. Thus, PAIRS provides an opportunity for the detailed investigation of short periodic nocturnal dynamics such as high frequency GWs, GW-tidal interaction, high frequency waves during convection and thunderstorm activity under varying geophysical conditions. In general, PAIRS is a field proven, and rugged instrument that makes it suitable for operation from multiple strategic locations to perform long-term observations.

doi : https://doi.org/10.1016/j.jastp.2023.106039

(Ravindra Pratap Singh, Duggirala Pallamraju, Pradip Suryawanshi, and Shashank Urmalia)

Latitudinal variations in the nocturnal behaviour of OI 630 nm airglow emissions and their relationship with equatorial electrodynamics

The latitudinal movement of the crest of the equatorial ionization anomaly (EIA) in both poleward in the evening and equatorward in the night has been reported using the OI 630 nm nightglow emissions. The EIA crest is found to shift away from the equator after the sunset, which has been shown to be directly related to the strength of the twilight time equatorial electrodynamics. Later in the night (after 20 LT), a clear movement of the crest back towards the equator, known as the reversal of EIA, was observed. The speeds of the EIA reversals for forty nights are found to be in the range of 10-55 ms^{-1}. As the global equatorial electric fields (E) are irrotational in nature ($\bigtriangledown \times$ E = 0), simultaneous variations in the daytime electrojet strength over Jicamarca in the American sector have been compared with the night time reversal speeds of the EIA over the Indian sector, which show a remarkable relationship with each other. Thus, it is hereby demonstrated that the reversal in EIA as inferred by the OI 630 nm nightglow emissions in our measurements is due to the westward equatorial electric field. It is hereby proposed that the reversal speed derived from optical nightglow measurements can serve as a proxy for the determination of westward electric field over equator for that longitude sector, which is otherwise very difficult to obtain and requires an expensive incoherent scatter radar.

doi : https://doi.org/10.1029/2022JA030401

(Saha, S., and D. Pallamraju)

Daytime vertical propagation speeds of gravity waves as precursors to equatorial plasma irregularities

The vertical propagation of gravity waves in daytime thermosphere has been shown to be a crucial parameter for the generation of ESF during post-sunset hours. This potential was applied to investigate the daytime gravity wave behaviour over the magnetic equator (using digisonde data from Trivandrum) with regard to assess the thermospheric conditions before the occurrence of plasma irregularities in the night. The results indicate that vertical propagation activity of gravity waves exists on 85% of the ESF days, whereas it is only 50% for the days without the occurrence of ESF during post-sunset hours. Further, vertical propagation speeds of these gravity waves are higher on the ESF days than on the non-ESF days. Also, ESF has been found to occur on 100% of the occasions, whenever the vertical speeds of these gravity waves are greater than 80 ms^{-1}. On such days, the peak altitude of the F-region also showed the same period as that of the gravity waves indicating that the high-speed gravity waves are capable of perturbing the ionosphere more efficiently on the ESF days compared to the non-ESF days. Further, the wavelet analysis showed that the gravity waves, their speeds and scale sizes that are present in the day continues until the time of the triggering of ESF irregularities in the post-sunset time. Thus, this threshold value of vertical propagation speeds of gravity waves ($>$ 80 ms^{-1}) can be used to predict the ESF occurrence around 12-14 LT on that day, which is much in advance of the occurrence of ESF [Figure no. 20].

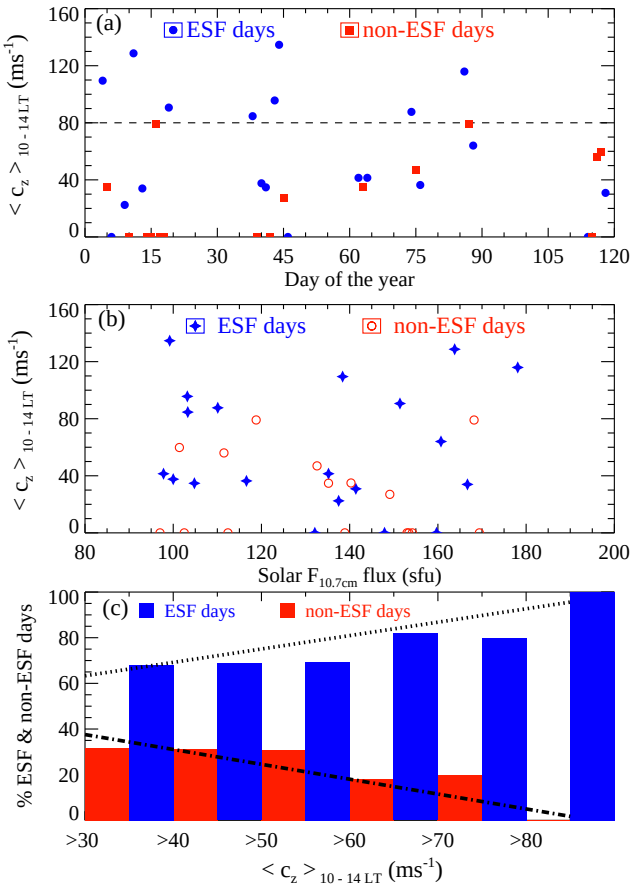

Figure no.20: (a) Daily average values of Cz during 10-14LT (ESF days: blue-colored circles; & non-ESF days: red-colored squares). (b) The valueof Cz showing larger values even on the days with low-solar F10.7 cm flux indicating its importance. (c) The percentage of the number of the ESF and the non-ESF days are categorized based on the values of vertical phase speeds of gravity waves in the daytime thermosphere. The leftmost red-colored bar indicates that 30% of the days are of the non-ESF category when Cz are greater than 30 ms^{-1}, whereas, for the ESF category, it is 65% (leftmost blue-colored bar). Similarly, the rightmost bar suggests that all the days are found to be of the ESF category if Cz is greater than 80 ms^{-1}. The dotted and dash-dotted lines show the trends for the ESF days and non-ESF days.

doi : https://doi.org/10.1029/2022JA030401

This work is done in collaboration with Tarun Kumar Pant, Space Physics Laboratory, Trivandrum.

(Mandal, S., and Pallamraju, D.)

Investigations of equatorial plasma bubbles as observed in the OI 630 nm nightglow emissions over off-equatorial and low-latitudinal locations over Indian longitudes

Equatorial plasma bubbles (EPBs), generated over the dip-equator during the sunset time, get mapped over to the low-latitudes through the geomagnetic field lines and contribute to structures of different scales in the nighttime thermosphere-ionosphere system. In the present study, the EPBs are observed in the OI 630 nm nightglow emissions over Mt. Abu and Kolhapur using a High Throughput Imaging Echelle spectrograph (HiTIES) and All-Sky Imager (ASI), respectively. Similar periodicities obtained in these measurements consistently corroborate the presence of the EPBs at both these locations.

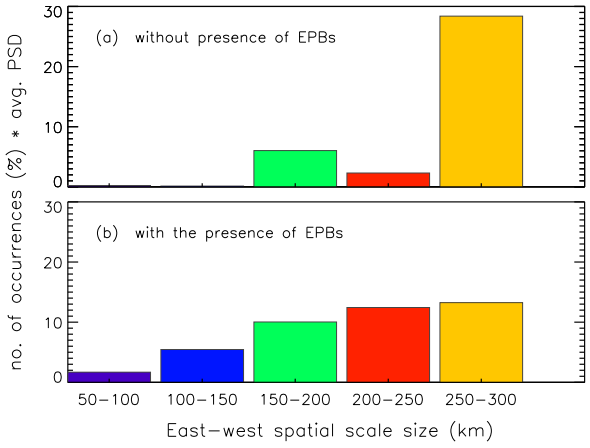

Figure no.21: The scale sizes which are segregated in 50 km grids are compared between the cases when the bubbles appeared in the image and when they did not. In the y-axis the collective effect of number of occurrence and PSD value for a given scale size has been shown by calculating the product of these two. The top panel includes all the images when the bubbles were not observed and the bottom panel shows the distribution of scale sizes when the plasma bubbles were observed in the images.

The strength of the Pre-Reversal Enhancement (PRE) in the zonal electric field has been investigated using the ionosonde data over Trivandrum, a dip-equatorial location. The strength of PRE decides the latitudinal extent of the EPBs. The eastward movement of the EPBs has been estimated to be in the range of 190-90 ms^{-1}, decreasing in magnitude from post-sunset to midnight. The wave number analysis carried out using the observed OI 630 nm emissions in the zonal direction has resulted in a contrasting behaviour during the presence/absence of the EPBs. Based on the analysis of around 1300 images of data, it is revealed that the scale sizes in the range of 250-300 km are omnipresent, whereas, shorter scale sizes (50-250 km) are present only during the presence of EPBs [Figure no. 21]. It is inferred that these shorter scale size gravity waves played a significant role in seeding the perturbation of the EPBs.

doi : https://doi.org/10.1016/j.asr.2022.08.023

This work is done in collaboration with R. N. Ghodpage, Medium Frequency Radar Facility, Indian Institute of Geomagnetism, Shivaji University Campus, Kolhapur, India.

(Saha. S., and D. Pallamraju)

Characterization of daytime thermospheric gravity waves in 3-D and estimation of horizontal neutral winds

Gravity waves, which are considered omnipresent in the Earth's upper atmosphere, are generally investigated by monitoring the fluctuations in different atmospheric parameters. Here, propagation characteristics of thermospheric gravity waves, both in horizontal and vertical directions obtained using collocated optical and radio measurements from Ahmedabad carried out during February 2021

are reported. The measurements of OI 630.0 nm dayglow emission rates over zenith are used to derive time periods of gravity waves. Wave number analyses of variations in the emission over a large field-of-view have been performed to derive gravity wave scale sizes and propagation characteristics in the horizontal direction. Time periods, horizontal scale sizes, and propagation directions are found to be in the range of 31-125 min, 78-243 km, and 203°-248° from east, respectively. Vertical wavelengths of the gravity waves are obtained from radio measurements and are in the range of 26-247 km. As the gravity wave characteristics are influenced by the ambient neutral winds, the measured gravity wave propagation characteristics in three dimensions have been used as inputs into the gravity wave dispersion relation to estimate the magnitudes of thermospheric horizontal neutral winds. These estimated daytime winds in the direction of wave propagation are found to be in the range of 1-105 ms^{-1}, and they compare well with those measured independently from MIGHTI added HWM14 model-derived winds. The daytime winds estimated by this approach are possibly the first of their kind as obtained from ground-based measurements.

doi : https://doi.org/10.1029/2022JA030954

(Kumar, S., Mandal, S., and Pallamraju, D.)

Development of a new daytime Airglow photometer for Space research (CDAP) for investigations of ionosphere-thermosphere phenomena

Airglow emissions that occur in the daytime are referred to as dayglow. It is a challenge to detect these dayglow emissions as the solar scattered background against which they occur is extremely bright. Thus, it is required that high spectral resolution measurements are carried out to delineate the difference between the dayglow signal and the solar scattered background brightness. A photometric technique to obtain daytime optical airglow emissions has been developed. In the method being described here, a low-resolution Fabry-Perot etalon is used as a high spectral resolution filter to obtain the dayglow signal. The spectral resolution achieved by this instrument is 0.026 nm at 630.0 nm, which is sufficient to separate the signal and neighbouring spectral regions for photometric measurements. The present technique builds up on the success of employing such methods in the past and brings in innovations that make it reliable, rugged, and suitable for unattended field operations. The details of the technique and the new elements brought in are described in this paper.

doi : https://doi.org/10.1016/j.jastp.2023.106025

(Pallamraju, D., P. Suryawanshi, S. Urmalia, S. Kumar, S. Saha, R. P. Singh, P. K. Kushwaha, and M. Soni)

Helium enrichment in interplanetary coronal mass ejections: new insights

Despite helium abundance [A_{He} = (n_{He}/n_H) × 100] being ∼8 percent at the solar photospheric/chromospheric heights, A_{He} can be found to exceed 8 percent in interplanetary coronal mass ejections (ICMEs) on many occasions. None of the proposed processes could explain the variability of A_{He} in ICMEs comprehensively so far. Based on an extensive analysis of 275 ICME events, we show that there is a solar activity variation of ICME averaged A_{He} values. We also found that the first ionization potential effect and localized coronal heating due to magnetic reconnection are not the major contributing factors for A_{He} enhancements in ICMEs. Investigation on concurrent solar flares and ICME events for 63 cases reveals that chromospheric evaporation in tandem with gravitational settling determines the A_{He} enhancements and variabilities beyond 8 percent in ICMEs (Figure 22). While chromospheric evaporation releases the helium from the chromosphere into the corona, the gravitationally settled helium is thrown out during the ICMEs. We show that the intensity and timing of the preceding flares from the same active region from where the CME erupts are important factors to understand the A_{He} enhancements in ICMEs.

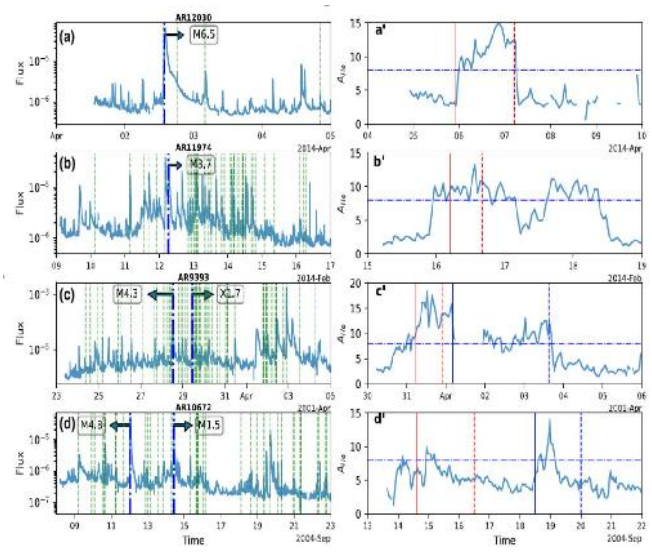

Figure no.22: The first two rows (a-a', b-b') are for CMEs associated with eruption of a single flare and multiple flares (before the onset of CMEs) respectively. These rows explain the role of chromospheric evaporation in enhancing A_{He} enhancements in CMEs. The last two rows (c-c', d-d') are for multiple CMEs erupting from the same active region. These events are used to understand the role of Gravitational settling. The green and blue lines mark the flare and CME onset times, respectively. The flares associated with CME is marked. The right panel shows the ICMEs with start, end times (dashed vertical lines) and A_{He}=8% level (dashed horizontal lines).

doi : https://doi.org/10.1093/mnrasl/slac044

(Yogesh, D. Chakrabarty and Nandita Srivastava)

Differential behaviors of suprathermal ^{4}He and Fe populations in the interplanetary medium during solar cycle 24

Investigations on the solar cycle variation of the properties of suprathermal populations (H and other heavy ions like ^{4}He, ^{3}He, C, O, and Fe) in the solar wind are sparse and hence poorly understood. In this work, solar cycle variations of "quiet" time suprathermal elements are investigated using $<\sim$ 1 MeV n^{-1} particle flux data obtained from the Ultra-Low Energy Isotope Spectrometer on board the Advanced Composition Explorer satellite during solar cycles 23 and 24. The analysis reveals that helium (^{4}He) shows zero or positive lags with

respect to sunspot numbers in solar cycle 23 while it shows zero or negative lag in solar cycle 24. On the contrary, although iron (Fe) shows a zero or positive lag in cycle 23 similar to ^{4}He, it shows only a zero lag in cycle 24 and no negative lag is seen. Further, significant differences in the spectral indices are seen between ^{4}He and Fe in cycle 24 compared to cycle 23 (Figure 23).

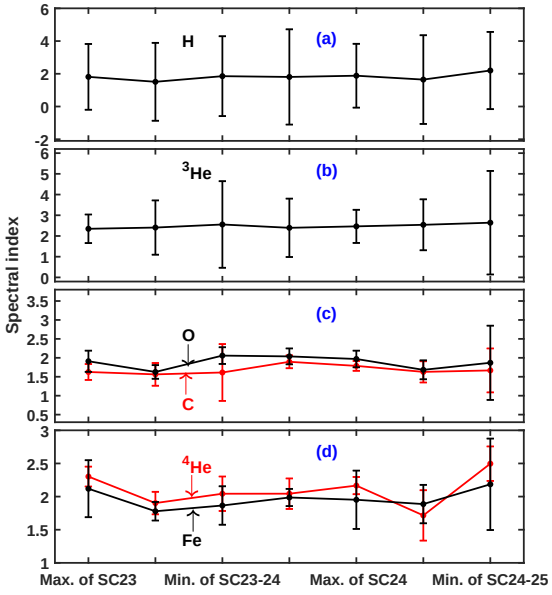

Figure no.23: Variations of spectral indices of (a) H and (b) ^{3}He and comparative variations of (c) C (red) and O (black) and (d) ^{4}He (red) and Fe (black) with respect to the different phases of solar cycles (SCs) starting from the maximum of SC23 up to the minimum of SC24-25. The margin of errors (MoEs) corresponding to the 95% confidence interval, in estimating the spectral indices are set as error bars. This figure shows that ^{4}He and Fe behave differently in SC24.

These results suggest that generation mechanisms responsible for suprathermal ^{4}He and Fe underwent changes in cycle 24 and these mechanisms are probably dependent on the first ionization potential and mass-to-charge ratio. This proposition gets credence from the fact that changes in the lags and spectral slopes for C and O are not significantly different in cycles 23 and 24.

doi : https://doi.org/10.3847/1538-4357/ac88d8

(Bijoy Dalal, D. Chakrabarty and Nandita Srivastava)

Solar flux dependence of postsunset enhancement in vertical total electron content over the crest region of equatorial ionization anomaly

Based on 10 years of vertical total electron content (VTEC) data in solar cycle 24 from Ahmedabad (23.0°N, 72.6°E, dip angle 35.2°), a station under the crest region of equatorial ionization anomaly (EIA), it is shown that both the integrated residual and total postsunset enhancements in VTEC are conspicuous during Equinox and December solstice when solar flux level exceeds 110 solar flux unit (sfu) with the exception of the year 2012-2013. The postsunset enhancements are absent in June solstice at this local time even if the solar flux level exceeds 110 sfu. The integrated residual and total VTEC enhancements during postsunset hours are found to be linearly correlated with the solar flux level in Equinox and December solstice. It is noted that a parabolic fit works better for the integrated total VTEC enhancement during December solstice suggesting a possible saturation of VTEC enhancements at high solar flux levels. Based on these observations and Thermosphere Ionosphere ElectrodynamicsGeneral circulation model (TIEGCM) outputs, it is argued that the prereversal enhancement (PRE) in the equatorial F region zonal electric field works in tandem with latitudinal gradient in the F region plasma density to determine the degree of VTEC enhancement over the EIA crest region during postsunset hours. These results highlight the solar flux dependence of the postsunset enhancement of VTEC over the crest region and show that sudden stratospheric warming events in 2012-2013 suppressed these enhancements in December solstice even if solar flux levels exceeded 110 sfu.

doi : https://doi.org/10.1029/2021JA030156

(Ankit Kumar, D. Chakrabarty, K. Pandey and A. K. Yadav)

Role of IMF B_y and substorm in generating anomalous electric field perturbations in the equatorial ionosphere during post-sunset hours

During a weak geomagnetic storm, the penetration electric field perturbations over the Indian dip equatorial sector are found to be anomalous on a number of occasions during post-sunset hours.

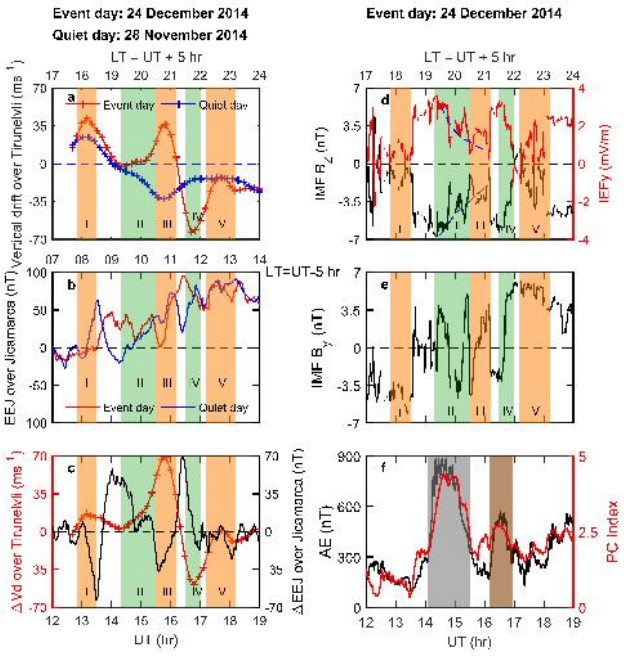

Figure no.24:(a) Vertical drift (V_d) over Tirunelveli, (b) Equatorial electrojet (EEJ) over Jicamarca, (c) ΔV_d over Tirunelveli (in red) and ΔEEJ over Jicamarca obtained by subtracting the quiet day from event day, (d) IMF B_z (in black) and IEF$_y$ (in red), (e) IMF B_y, (f) Auroral electrojet (AE) and polar cap (PC) indices marked in black and red lines respectively. Based on V_d variation over Tirunelveli on the event day, the intervals (I-V) are marked with orange and green rectangular boxes. Two peaks in AE and PC indices in panel f are marked with gray and brown rectangular boxes. Of particular interest is the in-phase variation of the ΔV_d and ΔEEJ in (c) in the interval II and large variations in interval IV.

The penetration electric field perturbations are investigated using the vertical drifts derived from the CADI (Canadian Advanced Digital Ionosonde) measurements at Tirunelveli (8.7°N, 77.7°E, dip angle: 1.7°). The post-sunset vertical drifts are considered "anomalous" as these variations in drift could not be explained by the dawn-dusk component of the interplanetary electric field (IEF_y) alone (Figure 24). By combining vertical total electron content over the Indian sector with the OI 630.0 nm airglow intensity from Mt. Abu, chain of magnetometer and Los Alamos National Laboratory geosynchronous satellite particle measurements, it is suggested that the anomalous penetration electric field perturbations on this night arise from the effects of Y-component of interplanetary magnetic field (IMF B_y) and substorm.

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This work is done in collaboration with B. G. Fejer [Utah State University, Logan, UT, USA], G. D. Reeves [Space Science and Applications Group, Los Alamos National Laboratory, US], D. Rout [GFZ German Research Centre for Geosciences, Potsdam, Germany], S. Sripathi and G. K. Seemala [Indian Institute of Geomagnetism, Navi Mumbai, India] and S. Sunda [Airport Authority of India, Ahmedabad, India].

(Ankit Kumar, D. Chakrabarty and A. K. Yadav)

Relative roles of IMF B_z and B_y in generating global asymmetry in ΔX variations during a geomagnetic storm

This investigation is directed to understand the asymmetry in ΔX variations caused due to the relative roles played by Interplanetary Magnetic Field (IMF) B_z and IMF B_y during the main phase of a strong geomagnetic storm event of 06 April 2000 (A_p = 236).

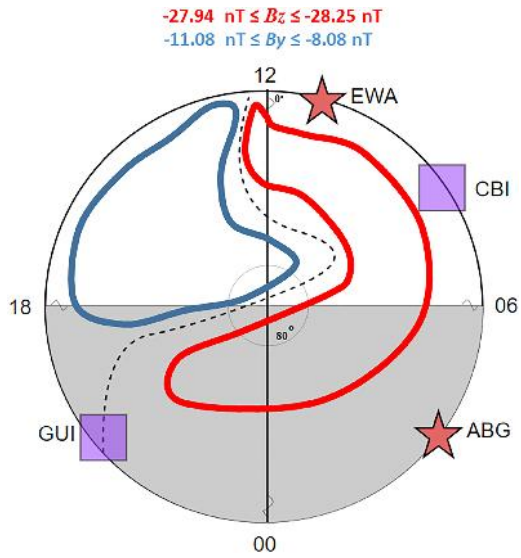

Figure no.25: A schematic of the DP2 equipotential contour under southward IMF B_z and negative IMF B_y condition during the region of interest (22:22-22:55 UT of April 06, 2000). The shaded (gray) hemisphere represents the nightside. The solid black line represents the midnight-noon meridian while the dashed black line represents the electrodynamical divider between the dawn (red) and dusk (blue) cells. The nearly antipodal station pairs are marked in violet squares for CBI (Japan sector) and GUI (European sector) and red stars for EWA (American sector) and ABG (Indian sector). ΔX variations over these two pairs of antipodal stations behave differently when IMB B_y acts in tandem with IMF B_z.

Two pairs of antipodal stations, being part of the SuperMAG network, are considered here. Observations show increases in the difference in ΔX variations between nearly antipodal stations from the Japanese-European/African sector with respect to the same between the nearly antipodal stations from the Pacific/American-Indian sector. This asymmetry is observed during the period when the absolute magnitude of IMF B_y is larger than that of IMF B_z resulting in a significant and conspicuous enhancement in IMF $|B_y/B_z|$. It is suggested that the distortions in DP2 cells and associated rotation of electrodynamic day-night divider, bring one pair of stations under the same DP2 cell and one station of the other pair under a different DP2 cell and throat flow region leading to the asymmetry in ΔX variations between the antipodal stations (Figure 25). Therefore, the work highlights the importance of the interplay between IMF B_z and IMF B_y in determining the ionospheric impact over low latitudes during strong geomagnetic conditions.

doi : https://doi.org/10.1029/2022JA031047

(Sumanjit Chakraborty and D. Chakrabarty)

SWASTi-SW: Space weather adaptive simulation framework for solar wind and Its relevance to the Aditya-L1 mission

Predictions of the solar wind parameters are the core of space weather forecasts. This work presents an indigenous three-dimensional (3D) solar wind model (SWASTi-SW). This numerical framework for forecasting the ambient solar wind is based on a well-established scheme that uses a semiempirical coronal model and a physics-based inner heliospheric model. This study demonstrates a more generalized version of the Wang-Sheeley-Arge relation, which provides a speed profile input to the heliospheric domain. Line-of-sight observations of GONG and Helioseismic and Magnetic Imager magnetograms are used as inputs for the coronal model, which in turn provides the solar wind plasma properties at 0.1 au. These results are then used as an initial boundary condition for the magnetohydrodynamics model of the inner heliosphere to compute the solar wind properties up to 2.1 au. This work showcases the multidirectional features of Stream Interaction Regions (SIRs) and provides synthetic measurements for potential observations from the Solar Wind Ion Spectrometer subsystem of the Aditya Solar wind Particle EXperiment (ASPEX) payload on board ISRO's upcoming solar mission Aditya-L1.

doi : https://doi.org/10.3847/1538-4365/ac8551

This work is done in collaboration with Prateek Mayank and Bhargav Vaidya [Department of Astronomy, Astrophysics and Space Engineering, IIT Indore].

(D. Chakrabarty)

Evidence for presence of a global quasi-resonant mode of oscillations during high-intensity long-duration continuous AE activity (HILDCAA) events

The responses of two High-Intensity Long-Duration Continuous AE Activity (HILDCAA) events are investigated using solar wind observations at L1, magnetospheric measurements at

geosynchronous orbit, and changes in the global ionosphere. This study provides evidence of the existence of quasi-periodic oscillations (1.5-2 h) in the ionospheric electric field over low latitudes, total electron content at high latitudes, the magnetic field over the globe, energetic electron flux and magnetic field at geosynchronous orbit, geomagnetic indices (SYM-H, AE, and PC) and the Y-component of the interplanetary electric field (IEFy) during the HILDCAA events at all local times. Based on detailed wavelet and cross-spectrum analyses, it is shown that the quasi-periodic oscillation of 1.5-2 h in IEFy is the most effective one that controls the solar wind-magnetosphere-ionosphere coupling process during the HILDCAA events for several days. Therefore, this investigation for the first time shows that the HILDCAA event affects the global magnetosphere-ionosphere system with a quasi-resonant mode of oscillation.

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This work is done in collaboration with Diptiranjan Rout [GFZ German Research Centre for Geosciences, Postdam, Germany], Ram Singh [Dept. of Astronomy and Space Science, College of Natural Sciences, Chungnam National University, Daejeon, South Korea], K. Pandey [ISAS, Department of Physics and Engineering Physics, University of Saskatchewan, Saskatoon, Saskatchewan, Canada], T. K. Pant and S. Thampi [Vikram Sarabhai Space Centre, Space Physics Laboratory, Thiruvananthapuram, India], C. Stolle [Leibniz-Institute of Atmospheric Physics, Kuhlungsborn, Germany], and T. Bag [Discipline of Physics, University of Kwazulu-Natal, Durban, South Africa].

(D. Chakrabarty)

Statistical investigation on equatorial pitch angle distribution of energetic electrons in Earth's outer radiation belt during CME- and CIR-driven storms

In this work, a statistical investigation (September 2012 - September 2017) of pitch angle distribution (PAD) of energetic electrons ($\sim$30 keV - 1 MeV) in the outer radiation belt (L $\geq$ 3) during CME- and CIR-driven geomagnetic storms is carried out using Van Allen Probe measurements. The pitch angle resolved electron flux measurements are obtained from the MagEIS instrument on-board Van Allen Probe-A spacecraft. We assume symmetric pitch angle distributions around 90° pitch angle and fit the observed PADs with Legendre polynomials after propagating them to the magnetic equator. Legendre coefficients c2 and c4, and the ratio R = $|c2/c4|$ are used to categorize the different PAD types. To resolve the spatio-temporal distribution of PADs, these coefficients are binned in 5 L-shell bins, 12 MLT bins for seven energy channels and four storm phases. We found that several hundreds of keV electrons exhibit clear dependence on local time, storm phases and storm drivers, with increased anisotropy for CME-driven storms during main and early recovery phases. On the contrary, we found that tens of keV electrons do not exhibit significant dependence on these parameters. We have discussed the different physical mechanisms responsible for the observed MLT dependent PADs and found drift-shell splitting to be the major contributor.

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This work is done in collaboration with I. J. Rae [Department of Mathematics, Physics and Electrical Engineering, Northumbria University, UK], G. D. Reeves [Space Science and Applications Group, Los Alamos National Laboratory, US], D. N. Baker [Laboratory of Atmospheric and Space Physics, University of Colorado Boulder, US].

(S. Chakraborty and D. Chakrabarty)

Ionospheric daytime conjugate hemispheric asymmetry along 100°E longitude: New insights

The hemispherical asymmetry of the low latitude region along 100°E $\pm$ 5°E is scrutinized for the year 2015 at magnetically conjugate points on seasonal and intraseasonal time scales. Two conjugate Ionosonde station pairs are selected- one pair in the inner valley (from SEALION) and the other in the outer edges of the EIA region. The anomaly in the stations is estimated using the difference of low latitude NmF2 from the dip equatorial NmF2 in the same meridian. The NmF2 observations suggest a close relation of hemispheric symmetry to the position of the subsolar point with respect to the dip equator and a shift/expansion of the trough region of the EIA towards the summer hemisphere. The inter-hemispheric comparison of the hmF2 suggests a strong modulating influence of meridional winds at both the inner and outer stations which depend strongly on the relative position of the subsolar point with respect to the field line geometry. Theoretical (SAMI3/SAMI2) and empirical model (IRI) simulations show a meridional movement of the EIA region with the subsolar point. The seasonal and intra-seasonal difference in the NmF2 hemispheric asymmetry is attributed to the misalignment of the two centers of power viz., the thermospheric/neutral processes and the electromagnetic forces, due to the geographic-geomagnetic offset in this longitude.

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This work is done in collaboration with B.R. Kalita, P.K. Bhuyan, S.J. Nath and M.C. Choudhury [Dibrugarh University, Dibrugarh], K. Wang [Space Weather Services, Bureau of Meteorology, Surry Hills, New South Wales, Australia], K. Hozumi [National Institute of Information and Communications Technology, Japan], P. Supnithi [King Mongkuts Institute of Technology Ladkrabang, Bangkok, Thailand], T. Komolmis [Chiang Mai University, Chiang Mai,Thailand], C. Y. Yatini [Indonesian National Institute of Aeronautics and Space, Indonesia], and M. Le Huy [Institute of Geophysics, Vietnamese Academy of Science and Technology, Hanoi, Vietnam].

(D. Chakrabarty)

Development of automation software for Short Wave Infrared Imager (SIRI)

Under PRL Technology development program a Short Wave InfraRed Imager (SIRI) for the investigation of small- scale gravity waves and transient features using OH nightglow emission in SWIR range is being developed. In SIRI, we have used 640x512 InGaAs photodiode array (PDA) with pixel size of 15 μm $\times$ 15 μm which is sensitive to light from 0.9-1.7 μm and is suitable for the observation of the brightest OH band nightglow emission originating from 87 km altitude. The present configuration of SIRI provides OH nightglow images with 30 meter spatial and 3 second temporal resolution that is sufficient for the investigation of the small-scale GWs and transient features present in the MLT region.

In order to automate the SIRI and to enable it for the seamless unattended operation as well as for data collection as per the predefined camera setting, a console-based application is developed. We have used various functions related to camera operations using the Software Development Kit (SDK) provided with the camera in python 3.10. This software uses universal initialization to setup root address of save file directory, schedule file path, root address of profile file, and place of operation and operating Mode. After initializing the camera, the software reads the schedule file for the start and end time and compares with the current time of the PC then it reads the profile file to set the desired camera settings (temperature, exposure time, gain mode). The acquired images are saved in fits format with time tagging in a directory named as year, month, day, and time such that the individual images are identified even for less than 1 sec exposure. This software keeps on taking exposures as per the predefined schedule and can be efficiently used for the long term observations. SIRI is being operated from the optical aeronomy observatory in Thaltej campus. The data analyses to derive gravity wave characteristics are under progress.

(Mohit K. Soni and Ravindra Pratap Singh)

Planetary Sciences

Modelling of Planetary Bodies and Atmosphere

Metallic ion layers in planetary atmosphere

Ablation of interplanetary dust in planetary atmosphere is a continuous process, resulting in formation of a metallic ion layer at certain altitude. Some past modelling and observational results show layers of metallic ions between ∼79 and 93 km altitudes on Mars. In the present work, we have shown production rates of different species generated due to dust ablation on Mars and Venus, using our ablation model. We used the existing Earth based observations to obtain a scaled dust flux for the orbit of Mars. Also, Galileo observations of dust over a heliocentric distance, covering 1.5 AU, are used to model a new velocity distribution of particles at Mars, as a more practical case. As such, any given production rate profile depends on many factors like atmospheric density, temperature, particle velocity, particle mass, dust flux and the error or uncertainty involved. To accommodate all such effects at one place, we have considered extreme cases of atmospheric condition and dust flux for the planet Mars. Our results (Figure 1) from ablation model show the altitude range for different metallic ions and neutrals, which are compared with past studies.

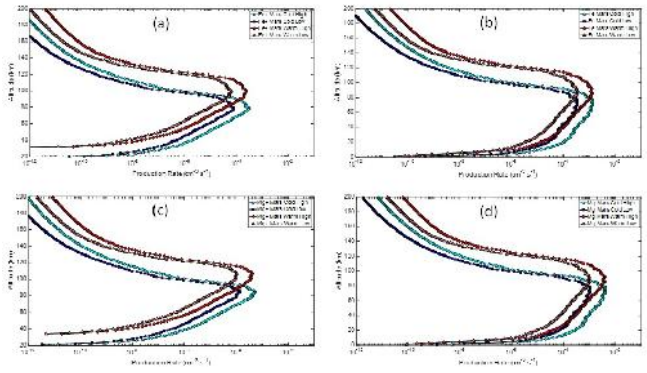

Figure 1: Ion and neutral production rates in the Martian atmosphere due to incoming carbonaceous chondrite meteoroids. The warm and cold conditions are described in legend as Warm (red diamond for high and orange triangle for low) and Cold (cyan circle for high and blue square for low), respectively. Similarly, dust input uncertainty on higher and lower sides are shown as High and Low in the legend. Martian profiles corresponding to extreme environmental and dust input conditions are shown for (a) Fe^{+}, (b) Fe, (c) Mg^{+} and (d) Mg.

Toward Venus, non-gravitational forces like P-R drag are prevalent during evolution of interplanetary dust particles. It is therefore, suggestive to use available observations of interplanetary dust, instead of a direct scaling, unlike Mars. In the present work, an interplanetary dust flux model (Figure 2) is proposed for Venus, based on the available observations of interplanetary dust. As a corollary, the mass flux of particles entering Venusian atmosphere is shown, which is an essential input in the ablation study. Further, a new velocity distribution model is presented from Galileo dust observations, covering heliocentric distance of Venus.

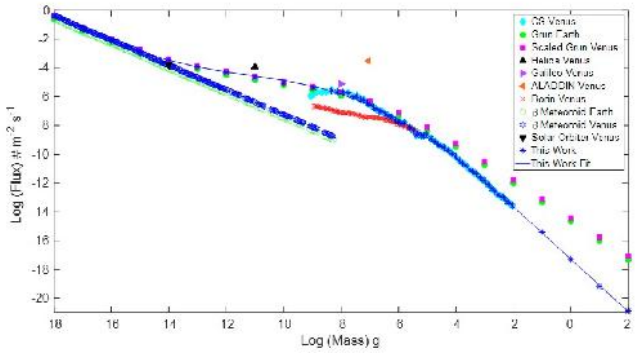

Figure 2: Logarithm of interplanetary dust flux versus logarithm of particle mass for various observations and models as follows. Flux at Venus in (cyan) diamond (Carrillo-Sanchez et al., 2020), flux at Earth in filled (green) circle (Grün et al., 1985), the scaled version of Grün et al. (1985) flux for Venus in filled (magenta) square, the flux observed by Helios in upward (black) triangle (Grün et al., 1980; Hirai, 2014), the flux observed by Galileo in right (purple) triangle (Krueger et al., 2010; Hirai, 2014), the flux observed by ALADDIN in left (orange) triangle (Hirai, 2014), the flux from the modelling in cross (red) sign (Borin et al., 2017), β meteoroid observations at Earth in open (green) circle, the scaled β meteoroid flux for Venus in (blue) hexag and the Solar Orbiter observations in downward (black) triangle. The proposed flux model for Venus is shown in (blue) asterisk, while its fit is depicted as (blue) line plot.

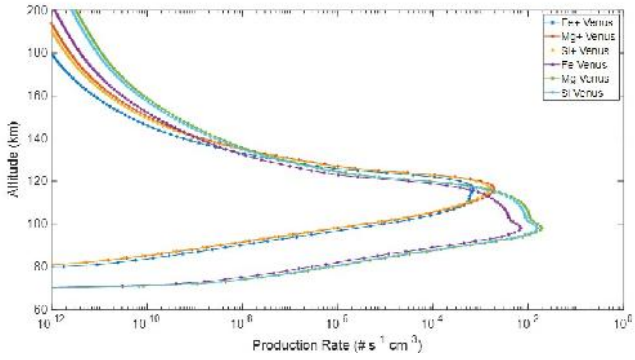

Figure 3: Profile of Fe^{+}, Mg^{+}, Si^{+}, Fe, Mg and Si in the Venusian atmosphere due to ablation of interplanetary dust with particles mass from 10^{-18} to 10^{2} g, whose flux is shown in Figure 2. The peak altitudes of ∼98 km and ∼116 km are found for neutral and ions on Venus, respectively.

Taking the proposed flux as an input in our ablation model, we find production rate for different ion and neutral species, produced by the dust. A parameter called Mass Ablation Ratio (MAR) is defined and its results are presented for Mars and Venus. From the MAR results, the threshold of the particle radii are found for Mars and Venus, for which greater than 75% of initial mass is ablated. The proposed flux model of dust at Venus can be useful as an input to ablation model and also,

to prepare for data analyses of upcoming space missions for Venus.

doi : https://doi.org/10.1016/j.pss.2022.105617

(J. P. Pabari, S. N. Nambiar, Rashmi and S. Jitarwal)

IDP flux at Earth, Its detection and Detector Response to High-Energy Particles

Interplanetary dust particles exist everywhere in the space between any two planets. These particles are originated from sources like Asteroid belt, Kuiper belt or comets and they evolve through their orbital paths. Various planets like Mars, Earth or Venus may capture such particles during their inward travel toward Sun. The flux of dust particles at a given planet is important to understand total inflow of material and also, metal ion layers formed in the atmosphere due to ablation.

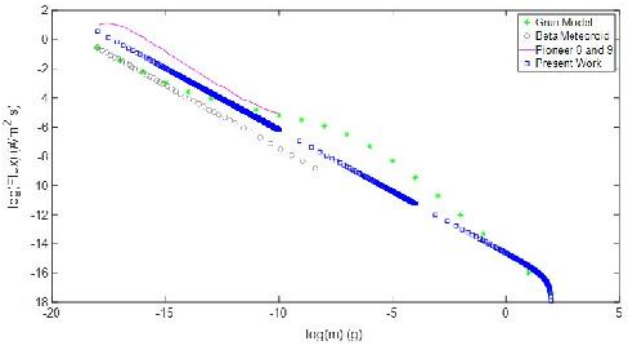

Figure 4: Logarithm of IDP flux versus logarithm of particle mass at Earth from Grün et al. (1985) model (asterisk sign in green color), β meteoroid observations (circle in black color), Pioneer 8 and 9 observations (line with magenta color) and the proposed flux model (square with blue color).

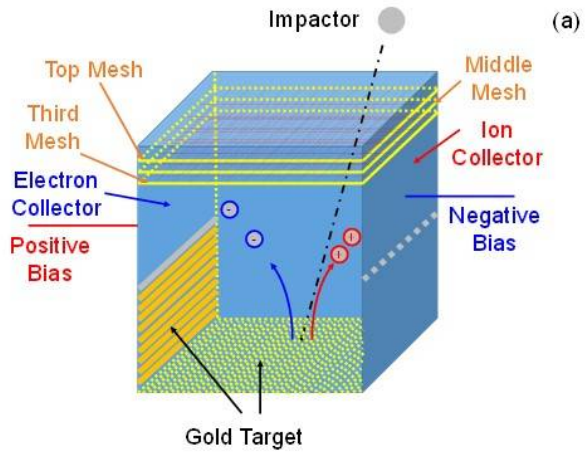

Figure 5: Schematic of dust detector. The plasma generated on impact of a hypervelocity dust particle is captured using voltage biased collector plates, which gives an idea about the particle properties.

Using past observations around Earth and an existing flux model, a power law model (Figure 4) is suggested for incoming particle flux at Earth. An upper limit of dust density around Earth is found to be 10^{-4} #/m^3, on an average. To detect such dust particles, an impact ionization dust detector (Figure 5) is proposed for planetary application and it is under development at PRL. A dust impact on detector target produces charge carriers, which are captured by voltage biased electrodes for further processing. For the dust detector, bias optimization is worthwhile to reduce resources required on board a satellite. In this regard, prediction of plasma capture efficiency is presented using SIMION software, to get first hand estimate of detector performance. In addition, the detector receives high-energy solar wind particles and Galactic Cosmic Rays in space, along with the dust. Therefore, understanding detector response to high-energy particles is utmost important during normal solar conditions and also during SEP events. Through an extensive simulation using Geant4 software and ACE, GOES as well as SPENVIS datasets, it is found that high-energy particles act as noise for the detector in electron channel only (Figure 6). The dust impact can easily be identified from the background noise using the signal coincidence. The results could be useful to understand dust flux at Earth and also for the detector optimization.

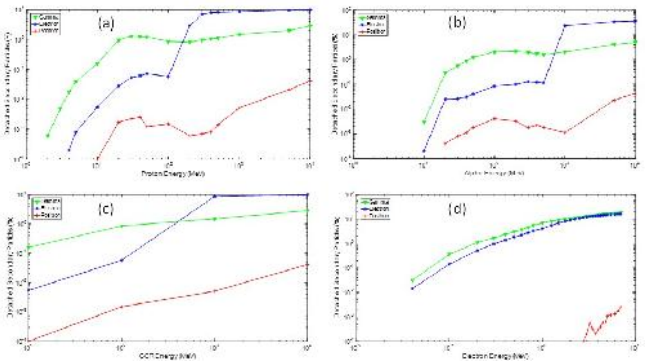

Figure 6: (a) Percentage of secondary electrons, positrons and gamma rays generated on impact of high-energy solar wind protons on dust detector. There is no response to the protons in lower energy range than shown. (b) Percentage of secondary electrons, positrons and gamma rays generated on impact of high-energy alpha particles on dust detector. There is no response to the alpha particles in lower energy range than shown. (c) Percentage of secondary electrons, positrons and gamma rays generated due to GCR on dust detector. (d) Percentage of secondary electrons, positrons and gamma rays generated due to high-energy electrons of the radiation belt on dust detector.

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This work has been done in collaboration with Dr. R. K. Singh, IPR, Bhat.

(J. P. Pabari, S. Nambiar, Anil Bhardwaj, K. A. Lad, K. Acharyya, J. M. Jakhariya, S. Jitarwal, Rashmi and V. Sheel)

Modelling electric permittivity of ice-rock mixtures and implications regarding permittivity-based ice detection techniques in the 1-1000 Hz range

Potential resources for future lunar exploration can be identified and further quantified by studying the near-surface structure of the Moon, up to depths of hundreds of meters. The lunar volatiles are expected to be preserved in cold traps or buried beneath the surface layer near the poles. We have considered the characterization of ice embedded in regolith materials, and used several mixing models for evaluating

the electric permittivity for the lunar subsurface. The frequency dependence of the electric permittivity is determined at temperatures 190 K and 220 K, over a frequency range of 1 Hz to 1 kHz for pure ices. Next, the electric permittivity of two component ice-rock mixtures are calculated for various ice-rock concentrations, and the implications for detection of lunar ice based on permittivity-based probes are discussed in this work. It is demonstrated that any mutual impedance probe proposed for a lunar lander (or rover) with an objective of ice detection requires to demonstrate a sensitivity for detecting permittivity variations of around a few percent over a frequency range of 1 Hz to 1000 Hz, if ice concentrations in the landing site are observed to be $\leq 1\%$. For higher concentrations of water ice, our modelling calculations show that the presence of ice can be revealed clearly from the frequency dependence of the real component of electric permittivity.

doi : https://www.currentscience.ac.in/Volumes/123/07/0841.pdf

(D. Banerjee)

First Comprehensive 3D Thermophysical Model for the Moon

We, at PRL, have built a comprehensive three-dimensional thermophysical model for the Moon to derive its surface and sub-surface temperatures for the first time. A unique feature of this model is its ability to account for lateral heat transport in three dimensions by utilising the actual topography of any location on the Moon to compute its realistic surface and subsurface temperatures at any scale (from few cms to several kms) (Figure 7). Such a model is not available till date. The model considers all plausible conditions and parameters to derive the temperatures and thermophysical parameters of the lunar surface and subsurface to represent the most realistic scenario. The model results compare well with laboratory experiments and validated using Apollo in situ measurements. The capability of the model is demonstrated by deriving the thermophysical behaviour of a small area of Apollo 17 landing site at both regional and local scales. This work has several applications both for lunar science and exploration aspects. To list a few, it can be used to constrain the nature of the outermost porous/dust layer. Knowledge of the nature of this surficial layer on a global scale combined with model calculations of the subsurface heat propagation can help in estimating the subsurface boundary showing the influence of solar insolation. This is an important input for planning the depth of deployment of heat flow probes of future geophysical experiments on the Moon. This information can also effectively be used a priori in determining the lunar heat flow values based on remote observations and theoretical modelling. The unique ability of the model to import any complex topography facilitates the derivation of thermophysical behaviour for any site of interest on the Moon to understand its local thermophysics that has significant implications on polar water-ice prospecting studies and in situ resource utilisation. Further, in combination with laboratory measurements, the model will help to interpret data returned from future in-situ experiments, such as ChaSTE experiment of Chandrayaan-3. This model will also help understanding the local thermal environment of any location on the Moon which is an essential aspect for future human exploration and lunar habitat. Importantly, this work gains significance in view of the recent renewed interest in lunar exploration and planned attempts to send humans back to the Moon.

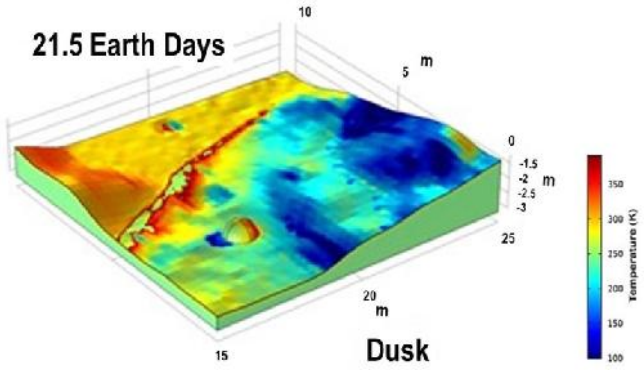

Figure 7: Image showing the model derived surface temperatures for a small 100 sqm. area of Apollo 17 landing site, during dusk time. A contrast temperature variation (ΔT = $\sim$300K) within the given area as predicted by the model shows its unique capability which was not available till date.

doi : https://doi.org/10.1029/2021EA001968

(K. Durga Prasad, Vinai Rai, S. V. S. Murty)

Unique regolith characteristics of the lunar swirl Reiner Gamma as revealed by imaging polarimetry at large phase angles

Lunar swirls are well known but the processes that led to the formation of lunar swirls remain contentious. The partial surface shielding from the solar wind flux due to a magnetic anomaly has been considered as one of the most commonly accepted hypotheses of the formation of swirls because swirls are found to be coupled to a localized magnetic anomaly region. Our objective of this study is to provide a quantitative assessment of the physical regolith properties at the Reiner Gamma swirl by deriving the opposition effect strength, surface roughness, and mean grain size information in order to shed light on the formation of the Reiner Gamma swirl.

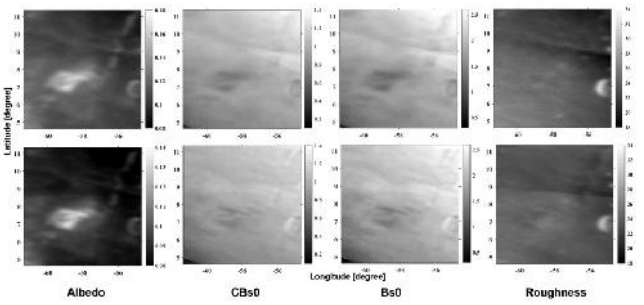

Figure 8: Derived Hapke parameter maps. The telescopic images were processed by blurring to uniform sharpness. The top row shows the parameters for the RC filter and the bottom row shows those for the GC filter.

We obtained the polarimetric observations using the 1.2 m telescope at the Mount Abu IR Observatory of the Physical Research Laboratory. We used the CCD based optical imaging polarimeter (EMPOL) developed in-house and acquired multiple sets of polarimetric images of the Reiner Gamma swirl and the ray systems of the craters Kepler and Aristarchus. The observations were collected with

the two narrow-band continuum filters GC (green) and RC (red), corresponding to central wavelengths of 525.9 nm and 713.3 nm, respectively. Hapkes bidirectional reflectance model is used to estimate the physical characteristics of the Reiner Gamma swirl. We derived the photometric roughness, $\bar{\theta}_p$, the volume-averaged single-scattering albedo, w, and the amplitude of the shadowhiding opposition effect B_{S0} by keeping all other parameters constant. The three free parameters were estimated per pixel by root mean square (RMS) minimization. The derived sets of resolved parameters are shown in Fig. 8 for the RC, and GC filters, respectively. The derived Hapke parameter maps with a spatial resolution of $\sim$1 km of Reiner Gamma shows that the microstructure of the northern tail varies with respect to the central oval of Reiner Gamma. The significant decrease in opposition effect strength and marginal reduction in surface roughness for on-swirl locations compared to the background mare suggests a smoothing and compaction of the uppermost regolith on the swirl. The results show that the high albedo of Reiner Gamma can be explained by its connection to the associated strong magnetic field, but the change in B_{S0} and the median grain size with a minor change in surface roughness is better explained by favoring the comet collision model for the formation of Reiner Gamma followed by preserved trends due to shielding by the crustal magnetic field that reduces solar wind interaction of the surface.

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This work has been done in collaboration with Prof. C. Wöhler and Mr. J. Rogall, Dortmund University of Technology, Germany.

(M. Bhatt, S. Ganesh, K. Aravind, A. Bhardwaj)

Moon: Electrostatics within Permanently Shadowed Craters on Moon

The local topography of the crater makes permanently shadowed craters (PSCs) over Moon electrically complex. The plasma environment in PSCs is generally characterized by diffused solar wind (SW) plasma. Its dynamics splits the crater into two distinct plasma regions, viz., electron rich region (ERR) and quasineutral region, which essentially describes the electric potential distribution on the craters surface. Herein, we discuss the electrostatic surface charging of PSCs and illustrate that the fine particles overlying the crater surface significantly contribute to establishing a finite electric potential on the crater surface. We depict that these fine particles act as efficient field emission centers generating electrons via quantum field tunneling and suffice in countering the diffused SW charging flux, establishing steady state charging equilibrium over the craters surface.

doi : https://doi.org/10.1134/S1063780X22600931

(S. K. Mishra)

Moon: Electrostatic Charging of Craters Surface over Sunlit Moon

Under direct exposure to solar UV radiation and solar wind plasma collection, the sunlit lunar surface undergoes electrostatic charging. The presence of surface relief results in non-trivial effects on surface charging and gives rise to complex electric potential and field structures. An analytical formulation describing surface charging within a simple crater is given using adequate solar radiation spectrum, solar wind plasma, and FermiDirac distribution of the photoelectrons. Lunar surface potential is determined by balancing the photoelectrons and solar wind plasma collection currents. The electric potential structures on the surface within a fully illuminated crater have been derived for different solar inclinations and solar wind plasma conditions. Two specific scenarios, viz. (i) normal photon incidence and (ii) oblique photon incidence, have been discussed. For normal photon incidence, the craters acquire positive potential. A finite region over the craters surface acquires negative potential for oblique photon incidence.

doi : https://doi.org/10.1134/S1063780X22600943

(S. K. Mishra and T. Sana)

Moon: Plasma sheath around sunlit moon: monotonic and non-monotonic structures

An analytical investigation of the sheath formation over sunlit moon under the influence of observed solar ultraviolet/extreme ultraviolet radiation and solar wind plasma has been presented. Poissons equation is coupled with the latitude-dependent Fermionic photoelectrons, non-Maxwellian solar wind electrons and cold ions to derive the electric potential, electric field, and population density profiles within the photoelectron sheath. We notice that the high-energy photons of the solar spectra in addition to Lyman-α, significantly contribute in determining the surface charge and subsequent sheath structure. A traditional Debye (Type C) sheath forms around the terminator due to dominant plasma electron accretion and marginal photoemission. While moving towards the equator, the photoelectron contribution increases, yielding monotonic (Type B) and non-monotonic (Type A) sheath solutions over sunlit locations. The calculations show that the non-monotonic potential structures are more stable near the terminator region, while both types of potential structures are probable near the equator region for the nominal solar wind plasma. A vertical sheath extension of $\sim$60 m and $\sim$12 m is predicted for typical solar wind plasma at the equator corresponding to Type A and Type B sheath, respectively. Under exotic plasma conditions (e.g., Earths magnetospheric tail lobe, plasma sheet), non-monotonic solutions become stable for the photoemission-dominated region, and the entire sunlit lunar surface may acquire negative potential.

doi : https://doi.org/10.1093/mnras/stad155

(S. K. Mishra and T. Sana)

Moon: Estimating optimum launch velocity of electrostatically detached dust particles over sunlit locations on Moon

Dust detachment is one of the fundamental issues which eventually drive the dynamics, kinematics and stability of the dusty plasma environment on Moon. In contrast to the earlier studies where detachment velocity was arbitrarily presumed to describe the dust dynamics within the sheath, we establish a framework deriving the

launch velocity of the electrostatically detached dust particles in the vicinity of the lunar surface over sunlit locations. We suggest: microscopic fluctuations over sunlit locations on Moon due to dominant photoelectric charging might induce a sufficient fluctuating electric field that can electrostatically detach the overlying charged dust grains by overcoming surface adhesion and lunar gravity. A formulation based on the dynamical evolution of the statistical variables, viz., the mean charge and the variance, at microscopic scale is established to calculate the local charge and electric field fluctuations and illustrate this effect. It is shown that the microscopic fluctuations could induce the charge (and subsequent electric field) variance by four orders of magnitude higher than the mean charge over the Moon's sunlit locations. The formulation has been coupled with the charged particle dynamics to derive the optimum launch velocity of the dust particles near the surface just after detachment. Fowlers treatment of the photoemission, dominant Extreme Ultraviolet (EUV) Lyman α radiation of the solar spectrum and subsequent collection of the emitted photoelectrons, measured particle size distribution of the regolith sample, and typical solar wind plasma are consistently accounted for illustrating the concept. We suggest that the intense fluctuations in the electric field locally detach the submicron-charged particles with a launch velocity of a few ms^{-1} for instance, the charge fluctuations might induce $\sim$ 10 Mv/m field that can launch 100 nm particles with a speed of $\sim$5 ms^{-1}. By specifying the launch velocity of the particle, the study bridges the gap in understanding the dust dynamics over Moon.

doi : https://doi.org/10.1093/mnras/stac3356

This work was done in collaboration with Mr. A. Bhatt of IIT Gandhinagar.

(S. K. Mishra)

Moon: Micro (nano) fabrication can mitigate massive charging from the objects operating within PSRs

Surface drilling could be a key operation in exploring permanently shadowed regions (PSRs) over the Moon in forthcoming missions. These processes might lead the massive charge build-up over the objects/ instruments operating in PSRs which itself confine complex diffused plasma environment. A scheme based on natural quantum electric field tunneling to mitigate the substantial charge deposition due to frictional charging from the drill setup, operating in the shadowed region of the Moon, is presented. We have shown that the micro (nano) structuring of the surface of the drill setup might efficiently support the charge dissipation. For instance, we demonstrate that the instrument surface fabricated with 10 nm spherical tips, operating in the electron-rich region within PSC, maintains itself to a much lower negative potential of $\sim$ 23 V it significantly contrasts with the planar surfaces where tribocharging dominates and develops a substantial negative potential of the order of $\sim$100 MV. The concept may be of practical significance in preparing test experiments for future lunar exploration campaigns.

doi : https://doi.org/10.1093/mnras/stac369

(S. K. Mishra and T. Sana)

M3 electron density layer in the dayside ionosphere of Mars: Analysis of MAVEN ROSE observations

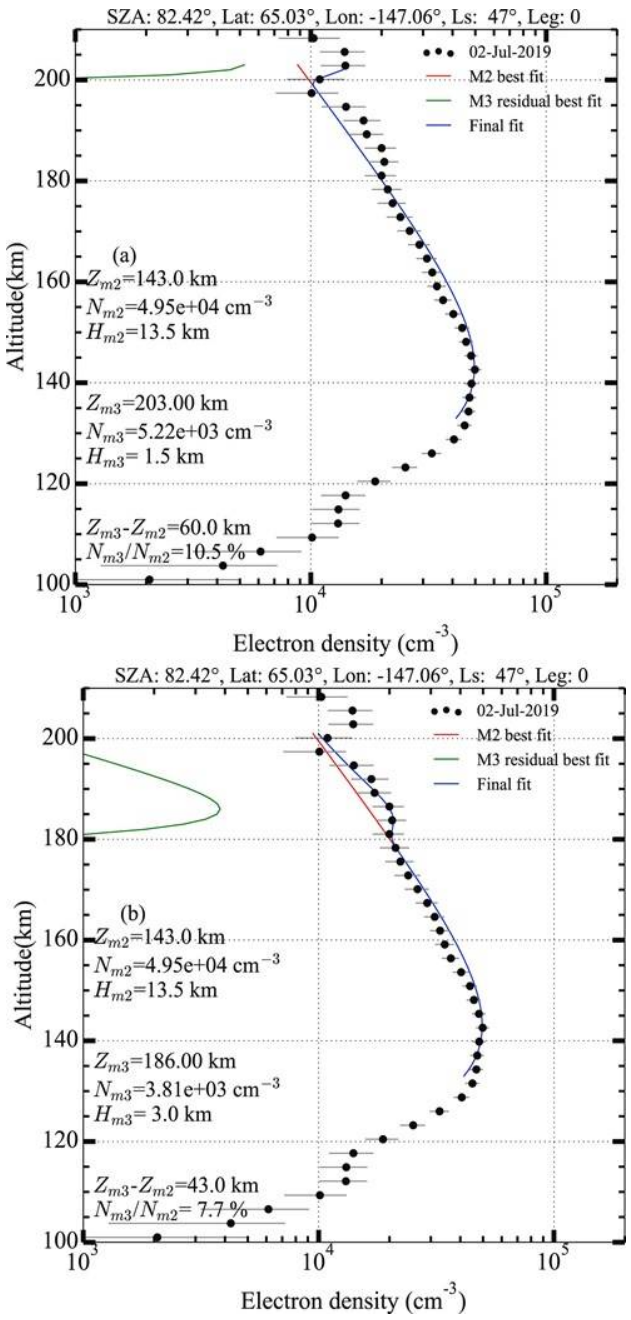

Figure 9: Chapman fit for ROSE profile measured on 02 July 2019. The scatter points represent the ROSE measured electron density profile. Uncertainties in the electron density measurements are shown in light gray horizontal lines. The red curve is the Chapman fit for M2 peak, and the green curve represents the fit for M3 peak. The blue curve is the sum of the M2 and M3 best fit curves. The peak density and altitude of the M2 (M3) peak is shown as N (N) and Z (Z), respectively. H and H represent the value of scale height used in the M2 and M3 best fit curves, respectively. First panel shows the case where the maximum altitude of fitting is set as 60 km above the M2 peak altitude. In the second panel, the maximum altitude of fitting is reduced to 58 km above the M2 peak. For the profile, reducing the maximum height of fitting improved the fit for M3 layer.

We have investigated the characteristics of the topside M3 layer in the Martian dayside electron density profiles obtained from the Radio Occultation Science Experiment (ROSE) onboard the MAVEN

spacecraft. M3 layer is a local enhancement in the electron density above the prominent ionospheric M2 peak. ROSE measurements have a wider latitudinal and solar zenith angle (SZA) coverage as compared to the spacecraft observations used by previous studies for characterizing the M3 layer. We analyzed 179 dayside (SZA $<$ 85 degree) electron density profiles from July 2016 to December 2020. The analysis show that the typical altitude of M3 layer is $\sim$180 ($\pm$10) km, with a density of $\sim$8 ($\pm$3) x 10^3 cm^{-3}, and occur $\sim$43 ($\pm$8) km above the M2 peak (Figure 9). These values are consistent with those reported by an earlier study using MGS RO data. The density of M3 layer seems to be insensitive to changes in SZA in the range of 55 to 85 degree. The increasing trend in the M3 peak altitude with increasing SZA might be indicative of M3 forming at constant pressure levels, similar to M2. In the northern hemisphere, both the M3 peak density and altitude seem insensitive to latitudinal changes. The most commonly cited reasons for the production of the M3 layer are the enhancement in the electron temperature and the converging vertical plasma motion caused by the crustal magnetic field. Our simulations using a one-dimensional photochemical model suggest that decreased dissociative recombination rate due to electron temperature enhancements may not contribute to the formation of M3 layer.

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This work is done in collaboration with Vrinda Mukundan of National Center for Earth Science Studies, Thiruvananthapuram and Smitha V. Thampi of Space Physics Laboratory, VSSC, Trivandrum.

(Anil Bhardwaj)

Atypically Intense and Delayed Response of the Martian Ionosphere to the Regional Dust Storm of 2016: A Study Using MAVEN Observations and Models

During Mars dust storms, atmospheric heating and expansion moves the ionospheric peak upward.

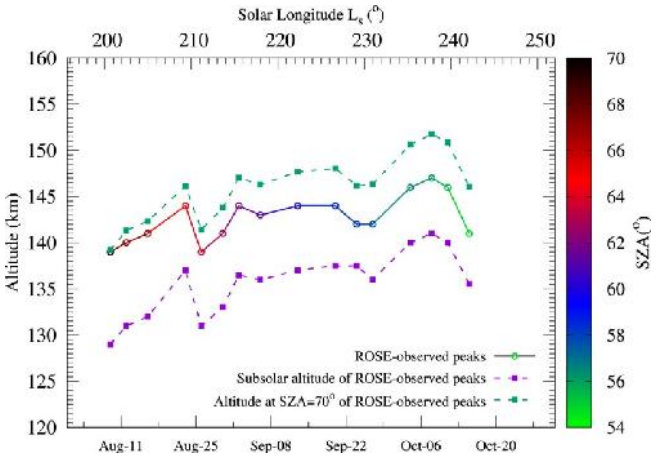

Figure 10: Radio Occultation Science Experiment (ROSE)-observed peak altitudes for the period AugustOctober 2016 compared with the subsolar peak altitudes and peak altitudes at solar zenith angle (SZA) 70°, both calculated using Chapman theory.

Typically, peak altitude increases by no more than 10 km, and this increase occurs simultaneously with the expansion of the dust storm. However, recent study of Felici et al. (2020) using the Mars Atmosphere Volatile EvolutioN (MAVEN) Radio Occultation Science Experiment (ROSE), reported an unusually large increase of $\sim$20 km at southern latitudes in early October 2016 during a modest dust storm (Figure 10). We investigate why the ionospheric peak altitude increased so much in these observations. We extend the time series of ionospheric peak altitude values beyond the limited extent of the ROSE observations by applying a one-dimensional photochemical model, in which neutral atmospheric conditions are based on in situ MAVEN Neutral Gas Ion Mass Spectrometer observations at similar latitudes and solar zenith angles to those observed by ROSE. We find that the ionospheric peak altitude was highest throughout October 2016 yet both the local and global atmospheric dust loading were greatest 1 month earlier. We hypothesize that (a) a portion of the unusually large 20 km enhancement in peak altitude and (b) the unusual delay between the greatest dust loading and the highest peak altitude were both associated with the occurrence of perihelion, which maximizes solar heating of the atmosphere, in late October 2016.

doi : https://doi.org/10.1029/2022JE007645

This work is done in collaboration with Vrinda Mukundan of National Center for Earth Science Studies, Thiruvananthapuram; Paul Withers and Marianna Felici of Center for Space Physics, Boston University, Boston, MA, USA; and Smitha V. Thampi of Space Physics Laboratory, VSSC, Trivandrum; and Francisco González-Galindo of Instituto de Astrofísica de Andaluca-CSIC, Granada, Spain.

(Anil Bhardwaj)

Observations and Modeling of Martian Aurora

Three kinds of auroras have been observed on Mars from Imaging Ultraviolet Spectrograph (IUVS) instrument onboard Mars Atmosphere and Volatile Evolution mission (MAVEN).

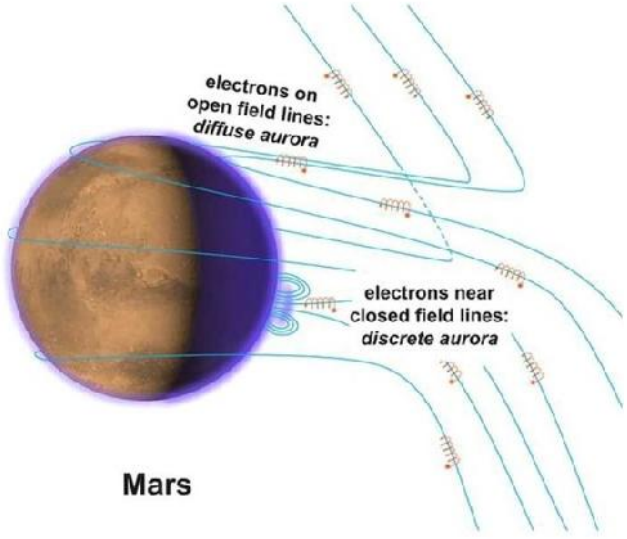

Figure 11: The magnetic field geometry for diffuse and discrete auroras on Mars

These are discrete aurora, proton aurora and diffuse aurora. The discrete aurora has been observed near the crustal magnetic field lines in southern hemisphere of Mars. This aurora is produced in the nighttime atmosphere due to precipitation of energetic electrons. The proton aurora is observed in the daytime due to energetic proton precipitation into the Martian atmosphere. During this event, Lyman-α limb profiles are enhanced at altitude between 120 and 150 km. The diffuse aurora is observed in the nighttime due to precipitation of SEP electrons down up to 1 microbar altitude. This aurora is neither restricted to location nor linked to the magnetic field. It is globally distributed and is closely correlated to solar wind velocity. The figure 11 shows the magnetic field geometry for diffuse and discrete aurora on Mars. Mars lacks global dipole magnetic field due to cooling of its core. The magnetic fields around Mars are the combination of small structures locked in the crust billion years ago and solar wind field lines draped around Mars.

doi : https://doi.org/10.1007/s11214-022-00906-2

This paper is written in collaboration with K. K. Mahajan, S.W. Bougher, N.M. Schneider, J. Deighan, S. K. Jain and J. C. Gérard.

(S. A. Haider)

Linking Atmospheric Chemistry of the Hot Jupiter HD 209458b to Its Formation Location through Infrared Transmission and Emission Spectra

The elemental ratios of carbon, nitrogen, and oxygen in the atmospheres of hot Jupiters may hold clues to their formation locations in the protostellar disk. A gas-phase chemical abundances of C, N, and O from several locations in a disk chemical kinetics model is adopted as sources for the envelope of the hot Jupiter HD 209458b and evolve the atmospheric composition of the planet using a 1-D chemical kinetics model, treating both vertical mixing and photochemistry. Two atmospheric pressure-temperature profiles are considered, one with and one without a thermal inversion. From each of the resulting 32 atmospheric composition profiles, it is found that the molecules CH_4, NH_3, HCN, and C_2H_2 are more prominent in the atmospheres computed using a realistic non-inverted PT profile in comparison to a prior equilibrium chemistry-based work, which used an analytical PT profile. The synthetic transmission and emission spectra for these atmospheres are also computed which show that many spectral features vary with the location in the disk where the planetary envelope was accreted. By comparing with the species detected using the latest high-resolution ground-based observations, the model suggests that HD 209458b could have accreted most of its gas between the CO_2 and CH_4 ice lines with a supersolar C/O ratio from its protostellar disk, which in turn directly inherited its chemical abundances from the protostellar cloud. Finally, simulation of observing the planet with the James Webb Space Telescope (JWST) show that differences in spectral signatures of key species can be recognized. This study demonstrates the enormous importance of JWST in providing new insights into hot-Jupiter formation environments.

doi : https://doi.org/10.3847/1538-4357/ac67f0

This work is done in collaboration with Spandan Dash and Liton Majumdar of NISER, Jatni Odisha, India; Karen Willacy, Neal Turner, and Murthy S. Gudipati of JPL, Caltech, Pasadena, USA; Shang-Min Tsai of University of Oxford, UK; P. B. Rimmer of Cavendish Laboratory and University of Cambridge, Cambridge, UK; and Wladimir Lyra of New Mexico State University, USA.

(Anil Bhardwaj)

The effect of metallicity on the CH_4 and CO quenched abundance in H-dominated atmospheres

Exoplanets show astonishing diversity in their parameter space, including atmospheric metallicity, which can significantly influence the atmospheric composition of exoplanets. We explored the effect of metallicity on composition in the presence of vertical mixing, a largely unexplored topic. Among the many methods to find transport abundance (in the presence of vertical mixing), we used the quenching approximation to constrain the transport abundance. The quenching approximation method defines the quench level at a pressure level where the chemical and mixing time scales become equal. Above the quench level, the transport abundance is given by the equilibrium abundance at the quench level (quenched abundance). Our equilibrium results are in good agreement with the literature. The CO-CH_4 and CO-CO_2 equal-abundance curves move to low-temperature and high temperature, respectively, with increasing metallicity. The abundance of CO and H_2O increases linearly, whereas CO_2 increases as the square of the metallicity. However, the CH_4 abundance increases with metallicity only in the low-temperature and high-pressure regions, where it is a significant atomic carbon source. The chemical time scale of CO is a weak function of atmospheric metallicity, but the chemical time scale of CH_4 decreases as the metallicity increases. CO quenched curve moves deeper into the atmosphere with increasing metallicity, while the quenched CH_4 is a complex function of metallicity. To benchmark the quenching approximation, we compared the output of the one dimensional photochemistry-transport model with the quench approximation for two test exoplanets. We found that the quench approximations are accurate within one order of magnitude and can be further improved using more accurate mixing length. We use the quench level data to constrain the mixing strength and atmospheric metallicity for four exoplanets: HR 8799 b, GJ 436 b, HD 189733 b, and WASP- 39 b. For HR 8799 b and HD 189733 b, we find that observational constraints of CH_4 and CO abundances and the quench level data can constrain the metallicity and Kzz. However, for GJ 436 b, we can constrain only the metallicity using the CO abundance, whereas the observed CH_4 abundance indicates a higher C/O ratio in the atmosphere. We also constrained the quenched abundances of CH_4 and CO for various vertical mixing strengths for WASP-39 b, which is among the first exoplanets whose atmosphere has been constrained by JWST.

doi : https://doi.org/10.3847/1538-4357/acb54e

(V. Soni and K. Acharyya)

Remote Sensing and Surface Science

Mare filled craters on the Moon

The lunar craters filled with lava materials represent direct evidence of post-modification processes, and such craters are globally widespread. This study mapped these craters and analyzed their diagnostic characteristics, such as approximate infilling lava depth, presence/absence of a central peak, and post infilling floor modifications. Nearly 324 mare filled craters identified, whose diameter ranges from ∼4 km to ∼270 km, with infilling lava depths varying from crater to crater and among regions (Figure 12). It is observed that the location of these craters is predominantly at the periphery of the mare region and at the rims of impact basins, while only a few are found in the highlands and within the mare/basins regions. These craters infilling age spans from ∼4 to ∼1.7 Ga, which is compatible with our current models of mare chronology. This study observed lava filling in several simple craters, which ought to be sourced from relatively shallower recent magma reservoirs. Nearly 54% of floor fractured craters (FFCs) are resurfaced and modified to different degrees by lava emplacement suggesting mare infilling within craters have witnessed multiple events.

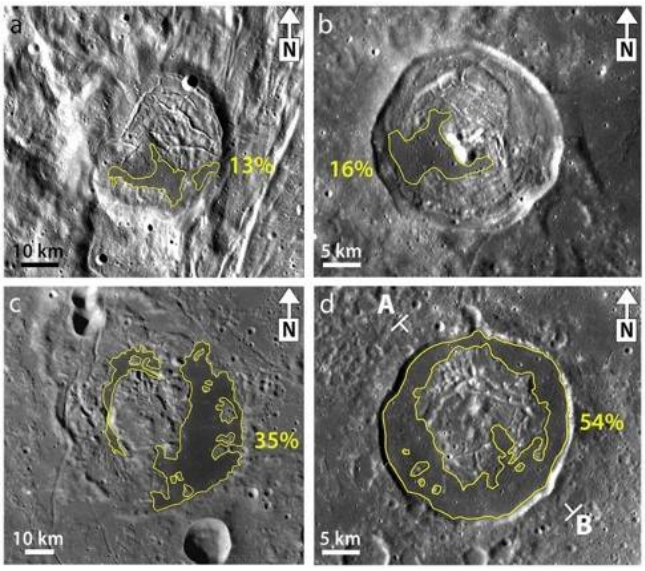

Figure 12: Examples of modification of Floor Fractured Craters (FFC) by mare infilling at different stages. a) 13% of the Fényi (45°S, 105°W), b) 16% of the Schubert C (1.9°N, 84.6°E), c) 35% of the Gerard Q (46.6°N, 83.1°W), and d) 54% of the Warmer (4.0°S, 87.4°E) floor area is modified by the mare units. These craters reveals comprehensive evidence that the FFCs are further modified by magmatic intrusions

doi : https://doi.org/10.1016/j.icarus.2022.115298

(Kimi K. B., Harish and Vijayan S.)

Compositional diversity in the Mare Marginis and Mare Smythii: An insight into the volcanism in the region

Mare Marginis (13.3°N, 86.1°E) is a large mare deposit lying north of the pre-Nectarian Smythii Basin (13.3°N, 86.1°E).

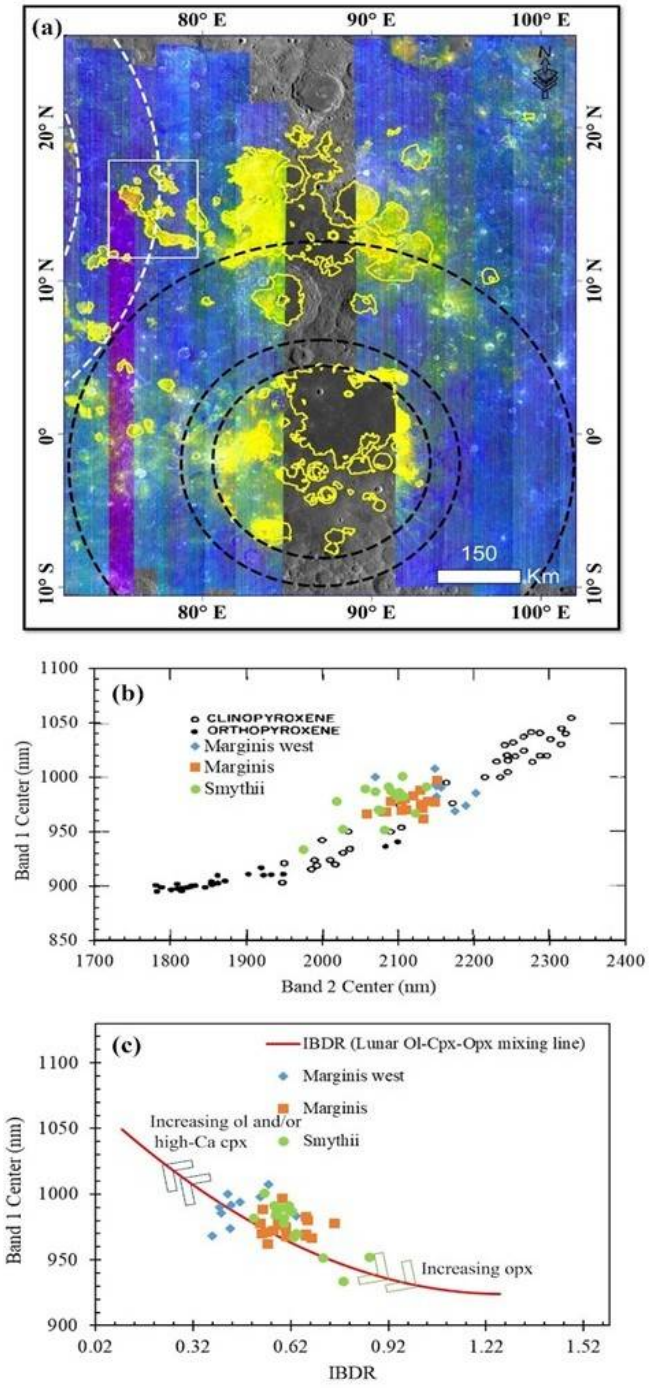

Figure 13: (a) M3 IBD-based FCC (R = 1000 nm IBD, G = 2000 nm IBD and B = Reflectance at 1489 nm) of the study area with LROC WAC as the base map. (b) BC1-BC2 plot and (c) BC1-IBDR plot showing the classification of the pyroxenes.

The unique setting of the Marginis-Smythii region at the eastern nearside-farside boundary of the Moon makes it an ideal site to better understand the lunar crustal asymmetry. A detailed investigation of the Mare Marginis and Mare Smythii basalts using the Moon Mineralogy Mapper (M3) data highlights the compositional diversity of these basalt deposits. The study reveals the presence of a spectrally distinct unit Marginis West in the region (Figure 13). Contrary to our prior

understanding of the volcanism in the region, it has been inferred that the volcanism in Mare Marginis was influenced by both; Crisium and Smythii Basins implying that the pre-existing structures in the lunar crust generated by large-scale impacts play an important role in the volcanism on the Moon.

doi : https://doi.org/10.1016/j.icarus.2023.115496

(N. Panwar, N. Srivastava, M. Bhatt and Anil Bhardwaj)

Consolidated chemical provinces on Mars: implications for geologic interpretations

For the first time, a set of consolidated geochemical provinces have been highlighted of Mars that has demonstrated an evolving chemical trend and indicated complex interior processes from the global surface composition. The chemical differences in the provinces suggest a diversity of mantle source and magmatic processes in volcanic areas, characterize possible global ashfall units, and evaluate the relative roles of igneous versus aqueous crustal provinces. Using GRS data and a new technique of three multivariate analysis methods, independently and in a consolidated form, a set of chemical provinces on Mars has been delineated. The results are also correlated with the mapped geologic units, that explained the geologic evolution of Mars on a global scale.

doi : https://doi.org/10.1029/2022GL099235

This work was done in collaboration with D. R. Hood, O. Gasnault, and S. Karunatillake (Scripps Institution of Oceanography, University of California, USA. National Institute of Polar Research, Japan; The Kyoto University Museum, Kyoto University, Japan)

(A. Rani, A. B. Sarbadhikari and S. N. Nambiar)

Discovery of Potential Caves in the Elysium Mons region of Mars

Martian caves are the potential destinations for future human habitats and astrobiological research. There are many pits on Mars, but some of them look like collapsed cave roofs. These special pits are formed by the collapse of surface materials into the subsurface void spaces. The signature of life is probable in the subsurface environment of Mars as it can protect life from the harsh and dangerous radiation environment of the surface. In a cave, there may be an abundance of minerals, fluids, and other key resources. Therefore, locating the access point of the subsurface cave is essential and crucial for formulating plans for robotic/human explorations of the Red Planet, Mars. In this study, we have identified, mapped, and classified a total of 32 special pit candidates using remote sensing data from Mars Reconnaissance Orbiter (MRO; NASA), Mars Global Surveyor (MGS; NASA), and Mars Odyssey (NASA). Out of these, 26 are newly found ones (Fig. 14). The thermal behavior of 23 special pit candidates is found to be similar to potential caves. In addition, cave entrances have been detected in nine candidates using data from the HiRISE camera onboard MRO.

doi : https://doi.org/10.1088/1674-4527/ac684f

Figure 14: An elevation map of Elysium Mons, Mars from MOLA data showing the location of the 32 special pits studied. The red stars, green dots, and blue triangles correspond to those classified as APC I (SP 1-11), APC II (SP 12-22), and APC III (SP 23-32), respectively. Out of 32 special pits, 26 SPs (SP 1-4, 6-12, 14-16, 18, and 21-31) are newly discovered ones.

The work has been carried out in collaboration with Ravi Sharma of JJT University, Rajasthan.

(N. Srivastava)

Morphological changes currently occurring in sand-filled gully channels on Mars: Implications for the role of substrates inside channels

Long-term monitoring of dune/non-dune gullies has substantiated extensive and diversified morphological changes whose timing correlates with the time of removal of CO_2 frost, thereby implying seasonal control on the active processes. We present evidence for present-day changes in sand-filled gully channels consistent with ripples. These channels are ubiquitous in the mid-latitudes and found in gullies formed over a variety of substrates on crater walls. We investigated 1483 gullied craters having coverage of at least two High Resolution Imaging Science Experiment (HiRISE) images between 30°S and 75°S and identified 98 craters (6.6% of the total) with sand-filled gully channels (Figure 15). Among these 98 craters, sand-filled gully channels in 25 craters (25.5% of the total) exhibit morphological changes indicative of avulsion, narrow channel incision, formation of channels with potential terminal pits, channel widening and extension, downslope flow of mobilized sand inside channels, dark flows and rapid boulder movement inside channels, and local sand rearranging and erasing of channels. Investigation of the sequence of events revealed CO_2 frost inside the sand-filled gully channels in the image acquired during winter and prior to the image in which recent changes have been observed. This suggests a connection with the sublimating frost inside the channels and a seasonal control that subsequently produces extensive changes in the sand-filled gully channels during defrosting seasons in approximately a Mars year. Comparison of changes on both sand-filled gully channels and dune gully channels substantiates that the currently active processes have similar effects on the loose, unconsolidated substrate in both the gully types. For example, CO_2 frost processes

are able to erode both sand-filled gully channels and dune gully channels to form linear channels with terminal pits. In contrast, we have not found similar evidence of linear channels with terminal pits on bedrock and/or LDM substrate on the crater wall suggesting that the bedrock and LDM substrate may not be able to be eroded by CO_2 frost processes in a manner similar to the loose, unconsolidated substrate in sand-filled gully channels investigated in this study. Together, the results signify that the sand-filled gully channels represent a significant component of present-day modification of gully channels on Mars.

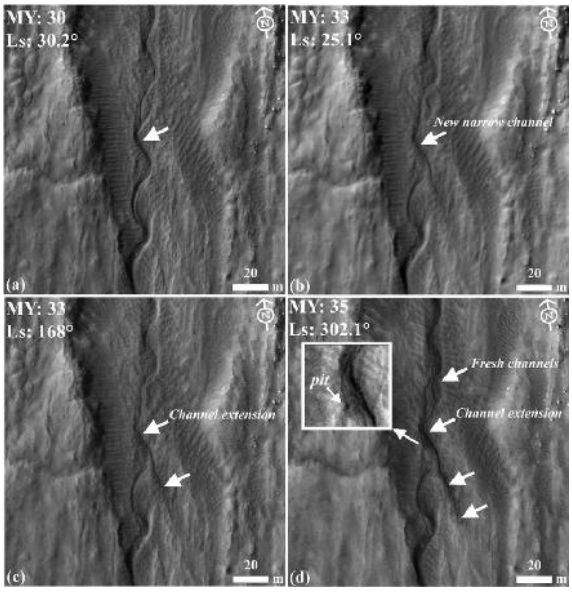

Figure 15: (a-d) Active flows in the upslope led to the incision of a new narrow channel (arrow in b) and subsequent extension of the channel (arrows in c and d) on the floor of a broad sand-filled channel in Gebog crater (37.25°S 124.11°E). Active flow in the upslope has led to the incision of fresh channels (upper arrow) in (d). Potential evidence of pit at the terminus of a channel (zoom image in Figure d) possibly indicates downslope transport of CO_2 ice block inside the channel. Sublimation of CO_2 ice block on reaching the terminus of the channel removed sand from beneath and formed a circular pit.

doi : https://doi.org/10.1016/j.icarus.2022.115334

(R. K. Sinha and D. Ray)

Ma'adim Vallis, Mars: Episodic and late-stage water activity at Tangtse crater

Alluvial fans, a form of sedimentary deposit reported on Mars, offer insight into the evolution and nature of fluvial activity on the planet. Ma'adim Vallis is an irregular-shaped, flat-floored valley incised due to the outflow of water from the Eridania basin. Craters on the Maadim Vallis are modified by the water flow and one such crater is explored in this study (Figure 16). The rim of the Tangtse crater is breached at multiple locations and it hosts an alluvial fan of an area $\sim$ 50 km^2. The CRISM spectral signatures show Mg-rich olivine and Mg-rich smectite. Mg smectite was plausibly transported through water or formed in situ while the underneath terrain was rich in Mg olivine. Tangtse crater age tend to be $\sim$3.7 Ga, and it witnessed the last-stage water activity from a resurged early Hesperian water activity in Eridania Basin. Tangtse crater formed on the floodplains of the Maadim Vallis providing an excellent opportunity for future landing missions to explore astrobiological significance of the region.

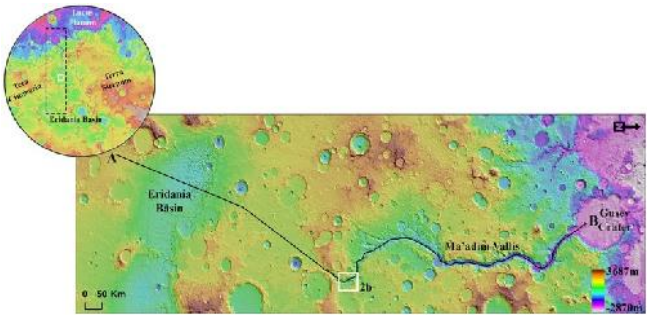

Figure 16: One of the longest valley on Mars named a Maadim Vallis. This valley terminated into the Gusev crater where the Spirit rover landed on Mars. The crater studied in this work is situated in the center of the valley.

doi : https://doi.org/10.1016/j.icarus.2022.115214

This work was done in collaboration with Tuhi S (Auburn University, USA), Harish (Khalifa University, K. Vigneshwaran, Govt College Salem,India. K.S. Sharini and R.K.S. Priya (Anna University, India)

(Vijayan S. and Kimi K. B.)

Shallow subsurface basalt layer along Cerberus Fossae, Mars

The subsurface structure along the Cerberus Fossae is fundamental to understanding the depositional history of the region.

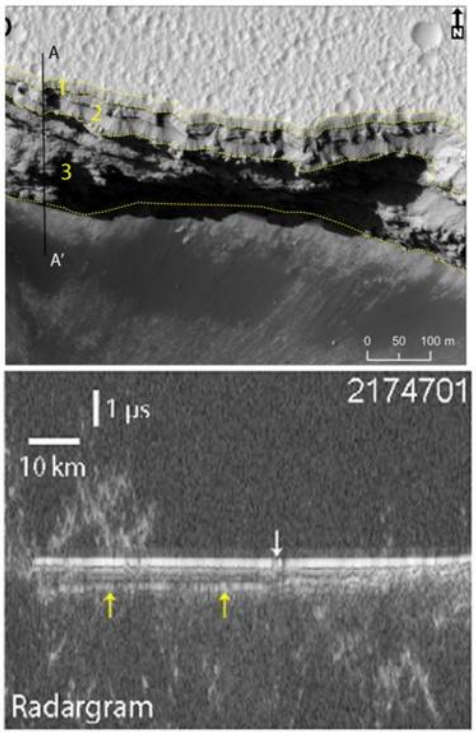

Figure 17: Exposed basaltic layers on the equator facing wall of Cerberus Fossae. The distinct units/contacts identified are marked by yellow dotted lines. The corresponding radargram and cluttergram with a reflector highlighted with yellow arrows.

Using MRO-SHARAD radar, the subsurface structure along Cerberus Fossae region were examined (Figure 17). This study found three distinct vertical units 1) ∼3 to 5 m thick regolith cover, 2) ∼30 m thickly layered unit, and 3) ∼260 m thick massive unit dominated by boulders. Using SHARAD radargrams, a subsurface reflector was identified, located ∼34 m deep. Our analysis suggests a real dielectric permittivity of 9.34±1.01 (1σ) for the shallow subsurface material, suggesting basaltic material. Using the dielectric permittivity mixing law, the porosity of this basalt is ∼4%. CRISM analysis suggests the presence of Fe-rich olivine along this region. Overall, a ∼30 m layered basalt along the Cerberus Fossae, which is older than 4 Ma indicated recent volcanic activity.

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This work was done in collaboration with Harish (Khalifa University, UAE, N Mangold (Laboratoire de Planétologie et Géodynamique, Nantes, CNRS), Tuhi S (Auburn University, USA), M.R. El-Maarry (Khalifa University, UAE)

(Vijayan S., Kimi K. B. and S. Baliyan)

Meteorite, Analogue and Laboratory Studies

Bulk and in-situ chemical analysis of meteorite Berduc, an L6 chondrite

A detailed petrological and geochemical study of L6 ordinary chondrite Berduc, which fell in 2008 in Colonia Berduc, Argentina, near the Argentine-Uruguay border have been documented. The meteorite is a unbrecciated, visibly unaltered sample, but bears evidence of localized melting. The bulk REE and refractory elements in Berduc are akin to that of the CI-chondrite, indicate that they were not mobilized from Berduc parent mass. However, the highly volatile elements are depleted as compared to CI-chondrite. Therefore, we have concluded that Berduc parent body have had a particular chemical behaviour, an open system allowing a substantial loss of the volatile elements as well as a closed system during and after the peak thermal metamorphism that allowed retaining most other elements. Perhaps the thermal metamorphism persisted under the influence of the internal heat source with the episodic loss of the volatiles depending on the duration of impact events. This duality in the physicochemical properties of Berduc could reveal the fundamental aspects of a parent asteroid evolution over time.

doi : https://doi.org/10.1007/s12040-022-02031-8

This work was done in collaboration with Maria E. Varela (ICATE-CONICET, San Juan, Argentina).

(A. B. Sarbadhikari, G. Arora and R. R. Mahajan)

Cosmic ray exposure history of ordinary chondrites using noble gases

Cosmogenic nuclides are produced in the meteorites by the interaction of energetic galactic cosmic rays during its journey in the interplanetary space as meteoroid. The duration from the time of ejection of meteoroid from parent body and fall on Earth, defined as cosmic ray exposure age, is calculated from the concentration of cosmogenic isotope ^{21}Ne. The cosmic ray exposure age provides information about past impact history in the parent bodies of meteorites. Ordinary chondrites fall over India and elsewhere were analysed for this purpose. Ordinary chondrites constitute the major mass in the total flux of meteorites impact on Earth. They are divided into three subgroups as H, L and LL chondrites based on abundance of metal. Bulk samples of ordinary chondrites from Indian falls, Mahadevpur, Jodiya, Jalangi, Devri-Khera, Katol, Didwana-Rajod, Itawa Bhopji, Kaprada (shown in red colour in figure 18) and other meteorites were analysed for isotopic signature of noble gases. The obtained exposure ages are plotted for histogram as shown in Fig. 18. The histogram of cosmic ray exposure ages of H and L chondrites shows several peaks. This indicates that there are several impact events occurred in the H and L chondritic parent bodies. Around 5 major peaks are observed in the histogram H type ordinary chondrite. L type ordinary chondrites shows more than 7 major peaks. This indicates that the origin of these meteorites was derived from different parent bodies. Essentially this is indicative that there were many impact events occurred in the asteroid belt.

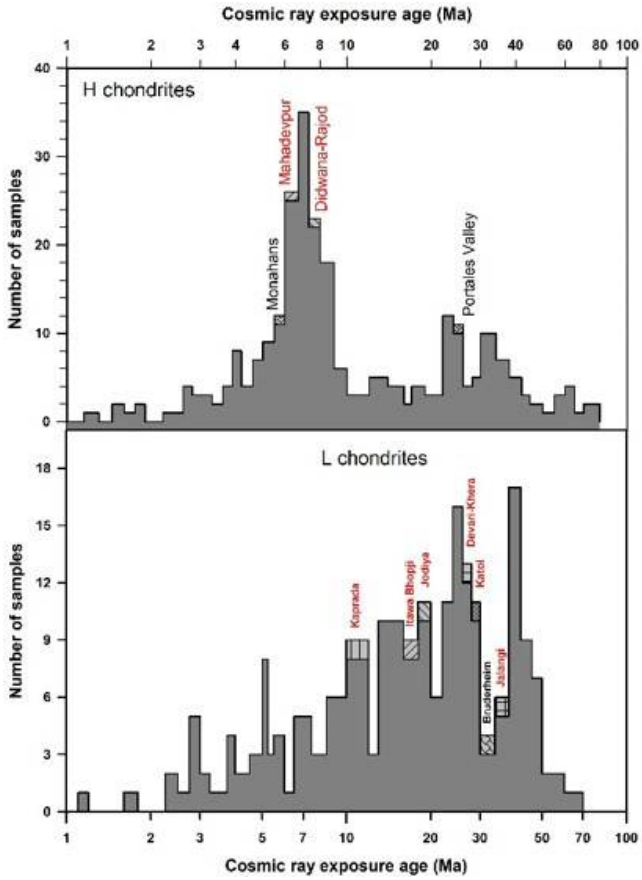

Figure 18: Histogram of exposure ages of ordinary chondrite samples

doi : https://doi.org/10.1016/j.asr.2022.06.037

(R. R. Mahajan)

Structural architecture of the iron meteorite: Implications for the process in the core of the differentiated asteroid

Without studying the iron meteorite and stony irons, our chance to examine the core of a differentiated body is far from complete. Though the earth has a substantial core, we never be able to sample from the interior. Therefore, the asteroidal impact and subsequent delivery to the earth in the form of meteorite is the best chance to get a free sample from the core of an asteroid. The iron meteorite - the best possible analogue of the core of any differentiated celestial body comprised intergrowth of Fe-Ni alloy (Fig. 19).

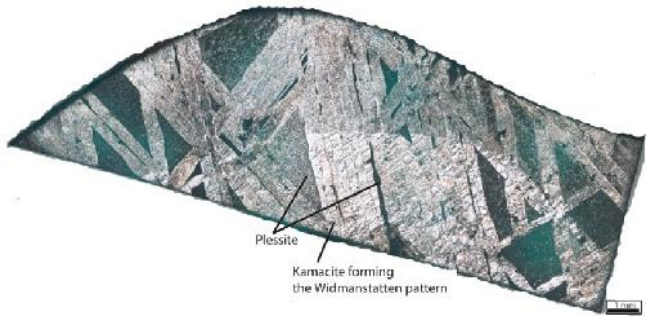

Figure 19: Reflected light polished section of Miller Iron MIL 03346. Note the Plessite and Widmansttaten pattern

The evidence of mild and moderate impact-induced compressive shock excursion and post-shock reheating (between 800° and 1000°C) is understood by the presence of shock twin lamellae and other microstructures like polygonization (between 2 GPa and 13 GPa). Further, accurate crystal orientation relationships and mineral chemistry provide insights into the formation mechanism and crystallization history (Fig. 20). The solid-state transformation (during the sub solidus cooling) of mineral phases processes is not straightforward as previously thought. The laboratory studies of iron meteorites including its microstructures, chemical compositions and shock characteristics are key and probably provide the best possible analogues in understanding and validate the future mission - Psyche (to explore the largest metallic asteroid 16 Psyche).

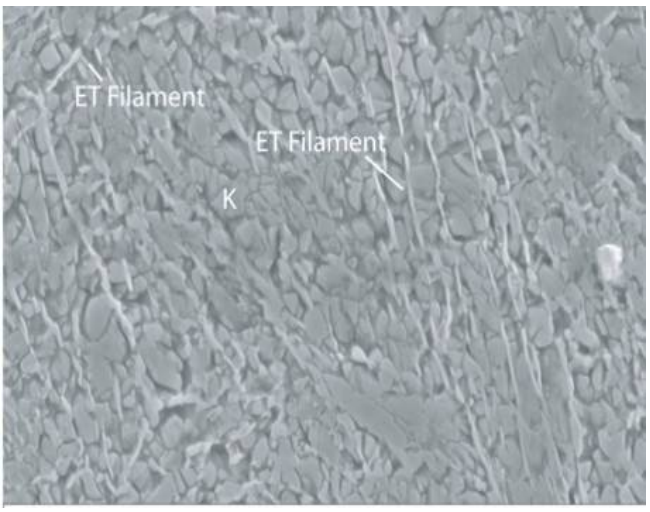

Figure 20: Exsolved Taenite (ET) filament in cuboidal aggregates of Kamacite

doi : https://doi.org/10.1016/j.pss.2022.105622

This work is done with collaboration with M. Paliwal, IIT, Kharagpur

(D. Ray)

A changing thermal regime revealed from shallow to deep basalt source melting in the Moon

A group of ancient lunar basaltic meteorites (3.9-4.35 Ga) were sourced from a cool, shallow, and compositionally distinct part of the lunar mantle, not previously sampled by any lunar returned sample missions. These findings have shed light on a poorly constrained aspect of early thermo-chemical evolution of the Moon and challenged previous understanding of mare basalt generation. This study has indicated a fundamental change in thermal and mantle melting regime in the Moon through time. Most of the Apollo mare basalts cluster around the age of 3.8-3.3 Ga and have been suggested to obtain from Procellarum KREEP Terrane (PKT). This study has proposed that the heat generated during the formation of the Moon, and that in the Moons interior, caused melting in the shallow KREEP-free lunar mantle.

doi : https://doi.org/10.1038/s41467-022-35260-y

This work was done in collaboration with J.M.D. Day, A. Yamaguchi, and A. Takenouchi, (Baylor University, USA; Universit*é* de Toulouse, France; and Louisiana State University, USA).

(Y. Srivastava and A. B. Sarbadhikari)

Petrogenesis of HED clan meteorites: Constraints from crystal size distribution

Crystal size distribution of diogenites and two eucrites meteorites are investigated. The result indicates multiple stages of melting, crystallization, and subsequent sub-solidus recrystallization in the deep-seated diogenites, while the eucrites underwent a lesser amount of metamorphism at a shallower crustal level than the deep-seated diogenites.

doi : https://doi.org/10.1007/s12040-023-02051-y

This work was done in collaboration with N G Rudraswami (CSIR-National Institute of Oceanography, Goa, India).

(B. P. Das, A. B. Sarbadhikari, Y. Srivastava and D. K. Panda)

Developmental Work **Venus Orbiter Dust EXperiment (VODEX)**

In solar system, Interplanetary Dust Particles (IDPs) evolve dynamically and may be captured by a planet on its way. Such IDPs, when passing through the atmosphere, get ablated and leave metallic ions in the lower ionosphere. It is essential to know IDP flux as an input to the ablation process for understanding the meteoroid layer in

the electron density profile. There are no measurements of IDP at and around Venus, except existence of a few measurements of IDP at larger distances from Venus. A Venus Orbit Dust Experiment (VODEX) is proposed for future Venus orbiter to study mass, speed and flux of IDP at and around Venus, and also between Earth and Venus. The detector fabrication and front-end electronic were demonstrated earlier.

(A) VODEX Processing Electronics: The analog signal generated due to a dust impact is processed further for obtaining pulse parameters. Recently, we have developed the FPGA based processing electronics and demonstrated its working. Figure 21 shows the end-to-end testing setup of the dust detector. The detector is tested at low input voltage level signals, generated using a function generator. The signal is provided to the collector plate of the detector, which tests Front-End Electronics (FEE), i.e., Charge Sensitive Preamplifier (CSPA), Buffer and Adder as well as the Processing Electronics (PE) in Figure 22, i.e., Analog to Digital Convertor (ADC), Digital to Analog Convertor (DAC) used for detector bias variation, Memory, Crystal oscillator and FPGA. Figure 23 shows the output of all four channels, i.e., two electron channels and two ion channels from the FEE.

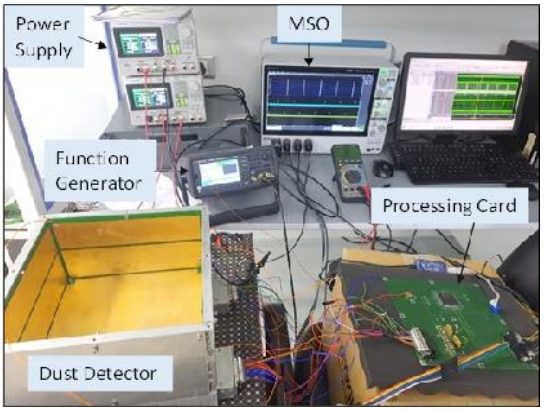

Figure 21: The end-to-end testing setup of the VODEX EM.

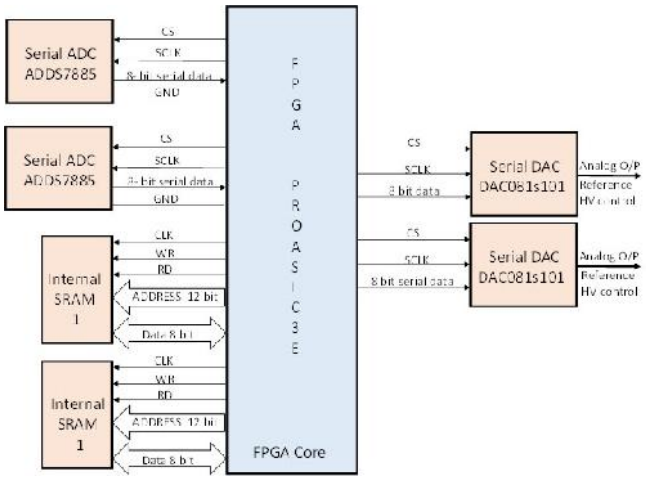

Figure 22: Block diagram of the VODEX processing electronics.

Figure 23: The FEE output for all four channels, i.e., two electron channels and two ion channels.

To acquire the signal from the FEE package, an ADC is used to convert analog signals to digital signals. The ADCs parameters, i.e., the sampling rate, number of bits and input range etc. are selected to achieve the required resolution in the measurable parameters of VODEX. Further ADC, DAC and internal FPGAs SRAM are interfaced and programmed using FPGA. Since the sampling rate of the ADC is high, which results in a huge amount of data consisting of dust impact event data and also the background noise. To remove the unwanted data, different processing algorithms have been tested like thresholding technique or peak detection. In thresholding technique, data above a certain threshold will be detected as valid data and will be saved into the memory and this threshold can be a variable that can be changed onboard using telecommand facility. Another technique called peak detection, is fully automated, which searches a peak with the onboard calculated threshold in a time of $\sim$3.3 ms and saves the data before and after the peak. Once useful data is detected, frames are formed with the header and footer, and are read out through the processing card to the (spacecraft) memory. Figure 24 shows digital output taken from the processing card connector, as observed on a mixed signal oscilloscope. Further work in terms of assembly of EM, having detector, front-end electronics and processing electronics was initiated and the assembly is in its final, optimization stage for its overall performance.

Figure 24: A digital frame, showing digital data having header and footer.

(B) Practical Testing of Optimum Bias Voltage: Further, the dust detector was tested at IPR, Bhat using a pulse laser. The nanosecond pulse laser setup at IPR, Bhat, Gandhinagar is utilised to simulate the charge generated by dust particle impact. Experiment was conducted to study the collection efficiency of pulse laser generated charges at different bias voltages of collection plates. The laser energy is kept

such that the primary process is the surface ablation, which produces plasma similar to a dust impact. The test was conducted at a laser energy of 180 μJ and the voltage bias was varied in the range of from 50-250 V (corresponding power supply setting was 100-500 V). Figure 25 shows that the highest collection of charges occurs around 200 V. However, because of vacuum being low, breakdown was observed for many signals at 500 V of power supply, which also resulted in tripping of power supply. On analysing rise-time of signals, no particular pattern of rise time with bias voltage was observed. However, delay in start of the signal did reduce with the bias voltage due to faster collection of charges, as expected. Further, it was observed that on operating laser at higher energy, the standard deviation or variation in measured laser energy is lower in single shot mode of the laser. Further testing is ongoing.

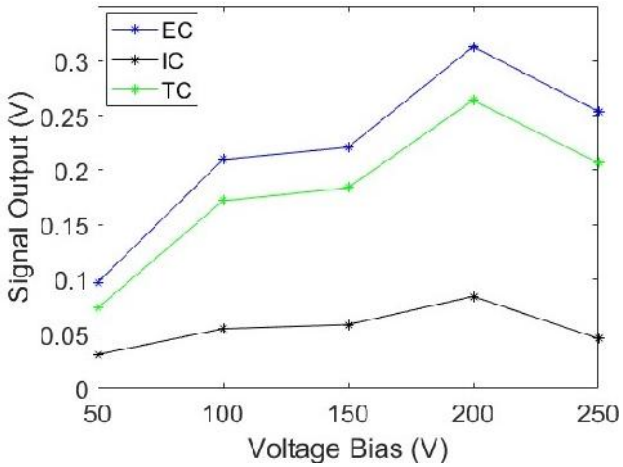

Figure 25: Output signal voltage vs Bias voltage for all the three channels. Peak is observed around 200 V.

(C) Variation in Laser Energy: The nanosecond pulse laser setup at IPR is utilised to simulate the charge generated by a dust particle impact. Recently, characterisation studies were carried out to understand the signals generated by the laser ablation. The laser is used in a single shot mode to simulate discrete dust particle impacts and for data storage. In the setup as shown in Figure 26 (a), much of the laser energy which is in few milli Joules, is diverted and only a small portion of energy (100s of μJ) is allowed inside the detector. However, variation is observed in the output signal from one shot to another and to probe this, the laser energy was separately analysed using energy meter. The energy of diverted beam is studied in single shot mode to derive relation between output from detector and laser energy. The measurement was carried out at different bias voltages as well. Figure 26 (b) shows the linear fit to the observed data for bias of 300 V. As observed, though there is rough correlation between laser energy and signal output, variations are observed from one shot to another. This indicates possible involvement of some other factors too which are being probed. For a given laser energy (measured from the diverted beam), the energy of laser beam directed towards detector could be varying because of low energy of operation, which can be studied as an extension of the current work, with the help of multiple energy meters. Such measurements will be useful in correcting the variation observed in the output signal.

A part of the work has been done in collaboration with Dr. R. K. Singh, IPR, Bhat.

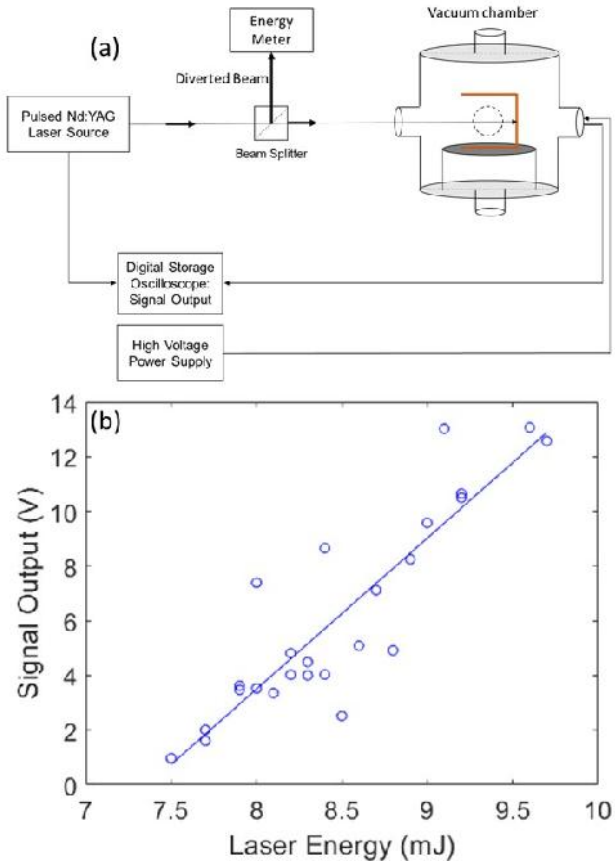

Figure 26: (a) The test setup where diverted beam and output signal from detector is shown. (b) Output signal voltage vs laser energy for electron channel along with a linear fit.

(J. P. Pabari, S. Nambiar, Rashmi, S. Jitarwal, K. Acharyya, V. Sheel, R. Mahajan, Anil Bhardwaj and Team)

Lightning Instrument for VEnus (LIVE)

A Lightning Instrument for VEnus (LIVE) is being developed at PRL for detection of lightning on Venus. A block diagram of LIVE is shown in Figure 27 where lightning signals are detected by an electrically short antenna and the signal is processed in the electronics. The development of Engineering Model (EM) of LIVE is initiated.

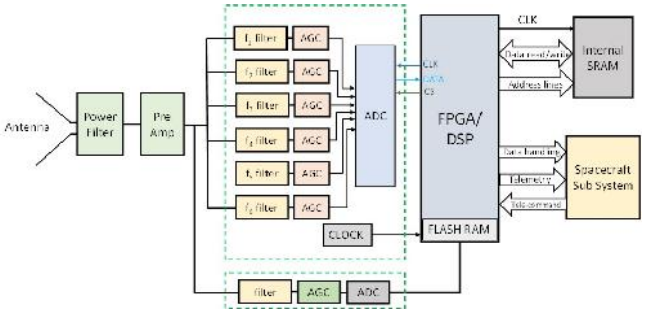

Figure 27: Design blocks of LIVE

The Figure 28 shows a 1.5 m antenna setup that has been made at PRL Thaltej Terrace for the detection of lightning during monsoon season as well as for field testing using a Van de Graaff generator. Initial test for sensitivity of the antenna was carried out using the Van de Graaff generator, by placing it at few meters away from the antenna and signal levels of $\sim$10 mV. A PCB has been made for front-end electronics of the LIVE, in which, two design options are implemented, i.e., a wide band signal with digital processing approach and a narrow band signal with discrete, analog filter approach. The wide band approach has a band pass filter with pass band frequency of 100 Hz to 30 kHz. For the second option, six discrete frequency filters having 30% bandwidth and center frequencies of 100 Hz, 300 Hz, 730 Hz, 5.4 kHz, 2 kHz and 30 kHz are implemented. Both the design options were tested in laboratory using a simulated pulse from the function generator, as depicted in Figure 29. For both the design options, the incoming signal is given to a notch filter for removal of power line pick up (50 Hz noise), followed by a pre-amplifier (AD524) for the signal conditioning. Figure 30 shows the output of the pre-amplifier stage (pink color). The input voltage level for testing was taken as 50 mV with a frequency of 1 kHz (blue color).

Figure 28: 1.5 m antenna set up on terrace of old building at PRL Thaltej campus.

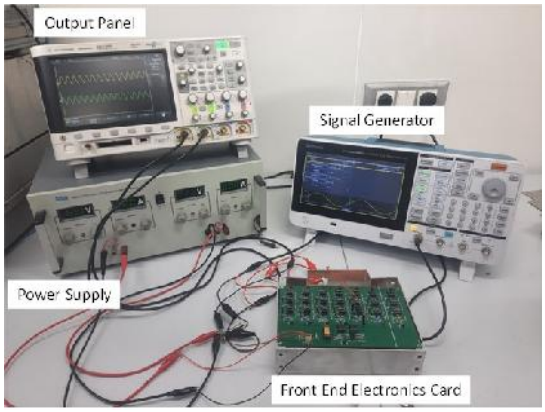

Figure 29: Testing setup for LIVE front end electronics card.

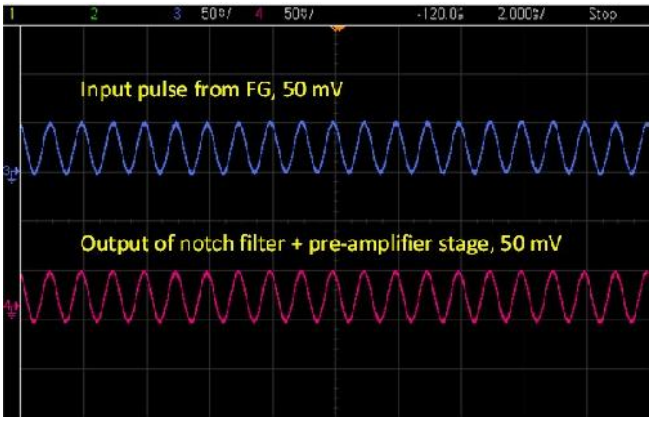

Figure 30: Output of first stage of front-end electronics card.

Further, for continuous monitoring of lightning signals, a data logging system is established using a Data Acquisition (DAQ) card and LabVIEW software. The lightning signals, which are captured by the antenna, will be taken as inputs to the DAQ card sampling at required rates. The card logs the captured data in a computer for post processing. Figure 31 shows the initial lab testing setup for data logging, where the signals are generated using a function generator and provided to a scaled version of the antenna. The output from the antenna is passed to the DAQ card and PC (LabVIEW software). The LabVIEW software plots the time domain signal captured by the antenna. It is further programmed to show Discrete Fourier Transform of the captured signal using Fast Fourier Transform (FFT) technique. It also shows the Short Time Fourier Transform (STFT) for the time-frequency localization. The required input parameters like sampling rate, number of samples, FFT size, frequency bins, time window for time frequency localization etc. can be changed by the user at any point of time through the front panel of LabVIEW software. Further work related to LIVE EM and the lightning station are going on.

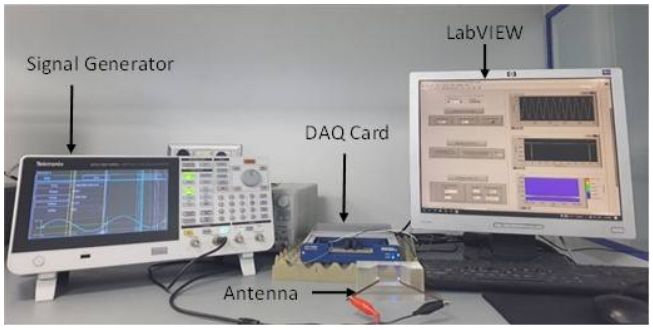

Figure 31: Lab-testing setup for data logging using a DAQ card and LabVIEW software.

(J. P. Pabari, S. Jitarwal, Rashmi, S. Nambiar, K. Acharyya, V. Sheel, Anil Bhardwaj and Team)

Development of a Miniature Meteorology Instrument for Mars and Venus

Exploration efforts of our two neighbouring planets, Mars and Venus, have been gaining momentum in the recent times as evident by series of missions planned in coming decades. One of the important aspects to be addressed is the meteorology and climate studies. Understanding the climate of Mars at various strategic locations is not only important to improve climate models/database but also essential to aid in situ robotic/human exploration in future and to determine if Mars could have the conditions to support life. One of the regions is the Planetary Boundary Layer (PBL) which is extremely important, both scientifically and operationally, because it is the region within which lander/spacecraft must operate. Till date, this region of the atmosphere has been studied directly, by landers, and from orbital remote sensing, though not to the extent that is necessary to fully constrain its character and behaviour. On the other hand, at Venus, balloons provide a unique platform to carry-out in-situ investigations in its middle atmosphere cloud regime. One of the important aspects that can be addressed only by experiments using Balloons is the understanding of cloud dynamics, regional scale turbulence, local meteorology which are the driving factors for the ongoing large scale phenomenon such as super-rotation, atmospheric dynamics, transport and coupling etc. To address these, we have proposed and developing a Miniature Meteorology Instrument. The plan is to deploy several of such instruments on the surface of Mars for spatio-temporal monitoring of meteorological parameters. Each device weighs $\sim$100 grams. The target parameters of measurement are Atmospheric Pressure, Temperature, Humidity, Winds, Solar Insolation and Imaging A laboratory prototype of the instrument is being designed and evaluated (Figure 32).

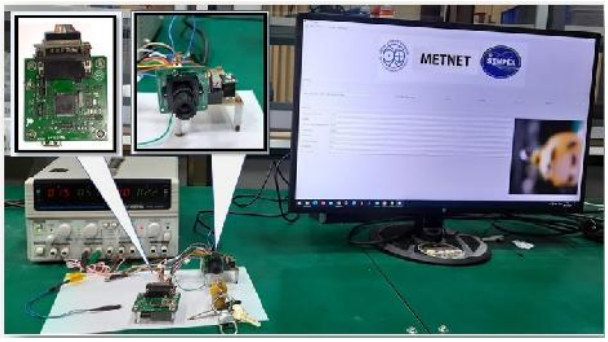

Figure 32: Evaluation Model of Meteorology Instrument. Controller Board and Sensing board with image sensor are shown in inset. A custom-developed GUI can also be seen in the picture.

The lab prototype consists of a PCB (5cm x5cm) based on an 8-bit micro- controller with a provision for interfacing multiple sensors. The instrument is also provided with USB and wireless communication capability for data transfer. A Python-based GUI is also being developed for real-time monitoring, display and logging of the MET data. The first version of the lab prototype is underway which contains a serial camera for imaging, pressure sensor, humidity sensor, IR and broadband Photodiode for ambient light monitoring and RTD-based temperature measurement. The PCB also houses conditioning and digital electronics unit for RTD and Humidity Measurements.

(K. Durga Prasad, Chandan Kumar and V. Sheel)

Supra Thermal & Energetic Particle Spectrometer (STEPS) - Subsystem of ASPEX payload

STEPS is one of the independent subsystem of Aditya Solar wind Particle EXperiment (ASPEX), which is going to be flown on Aditya - L1 mission. The spacecraft is going to be placed in a halo orbit around the Sun-Earth L1 Lagrangian point. ASPEX will measure the slow and fast solar wind, supra-thermal particles and solar energetic particles using its two subsystems: SWIS (Solar Wind Ion Spectrometer) and STEPS. STEPS covers the high-energy spectrum of the particles i.e. in the range of 20 keV/n to 5 MeV/n from six directions i.e. Sun-Radial (SR), Parker Spiral (PS), Earth Pointing (EP), Intermediate to SR and PS, and North & South of the Sun-Earth ecliptic plane. The STEPS subsystem has been configured into three packages in order to cover the six directional measurements i.e. STEPS-1, STEPS-2A & STEPS-2B. STEPS-1 package houses four detector units (SR, IM, PS and NP) and their front-end electronics (FEE). STEPS-2A package has one detector unit (EP) and FEE for EP and SP (STEPS-2B) detector units. ASPEX-PE is a processing electronics package, common for both SWIS and STEPS.

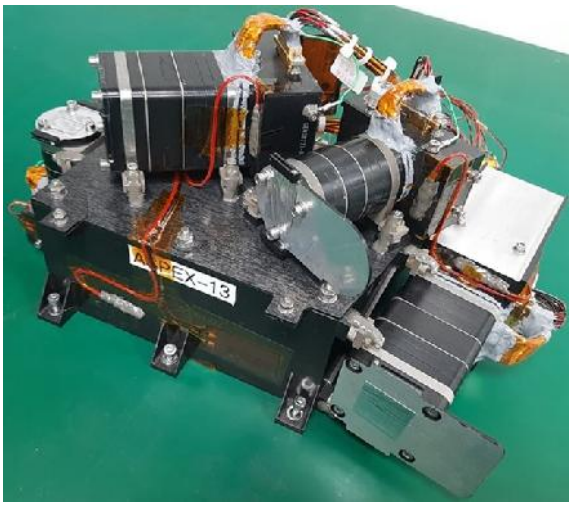

Figure 33: Flight model of the STEPS-1 packages.

Figure 34: Flight model of the STEPS-2A & STEPS-2B packages.

Flight models (FM) and Qualification models (QM) of the STEPS and

ASPEX-PE have been developed and tested. Flight models of the STEPS are shown in Figure 33, Figure 34 and Figure 35.

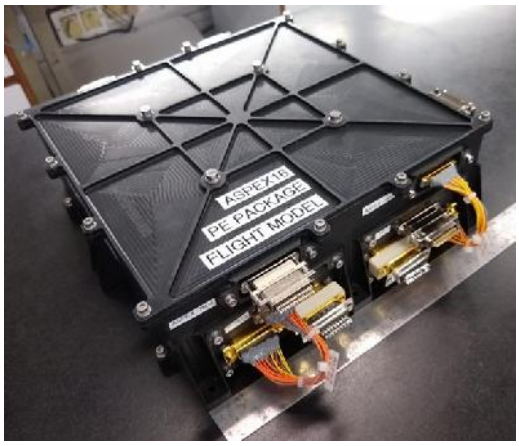

Figure 35: Flight model of ASPEX-PE package.

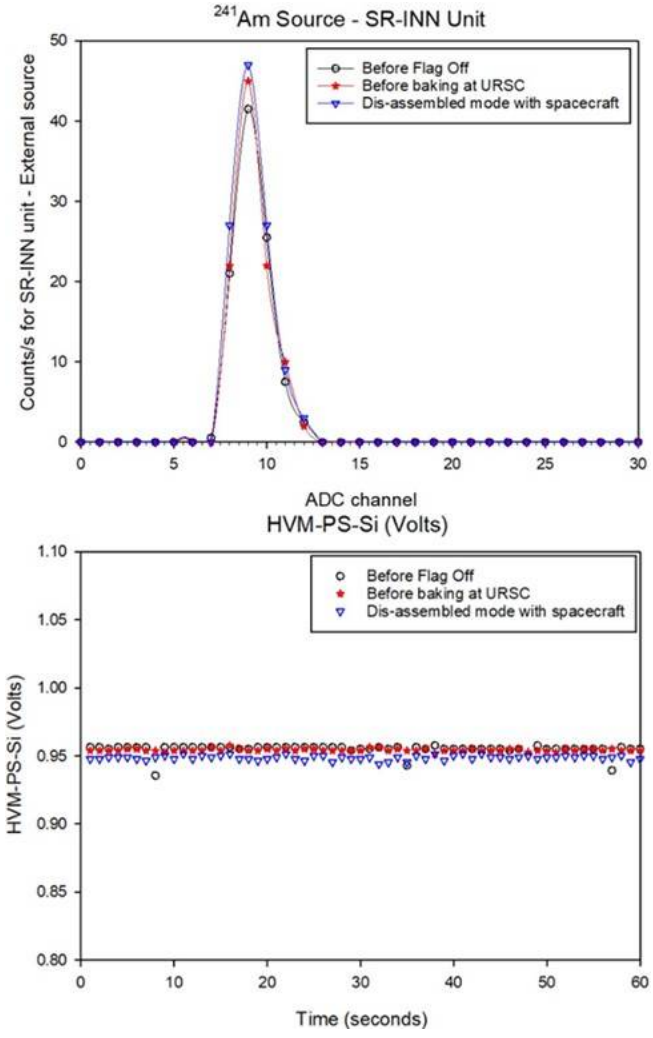

Figure 36: Over-plots of SR-INN detector using ^{241}Am source and HVM-PS-Si Voltage, during functionality test for pre-flag off, pre-baking and spacecraft disassembled mode

Test & Evaluation (T&E) tests for STEPS-FM have been successfully completed and cleared by the T&E committee. The thermal balance tests of the packages were carried out to verify the thermal simulations. Flight models have been delivered to the project. After the delivery of the project, STEPS packages were interfaced with the spacecraft sub-systems for the integration checks, power on tests, performance tests etc. These dis-assembled tests of the payload with Aditya-L1 spacecraft have been successfully completed without any change in the performance. The over-plot using ^{241}Am source for SR-INN and over-plot of HVM-PS-Si voltage (one of the health parameter) are provided in Figure 36. Over-plots of the spectrum and housekeeping parameters show no change in the performance. In Figure 36, it is seen that count rate is different for pre-flag off, pre-baking and space-craft dis-assembled mode measurements which is expected due to the manual handling of the source position. The peak channel of the energy is coming on the same channel number, showing no-change in the performance.

STEPS-QM have also undergone the EMI/EMC tests at URSC-Bangalore which were completed successfully. Along with this, magnetic field leakage tests in power-off condition at ISITE-campus of URSC was also completed where leakage value from the packages is negligible ($<$20nT). STEPS-QM packages have been subjected to the Sun-simulator tests at LEOS-Bengaluru for the verification of the Field of View (FOV) of each of the detector units.

STEPS instrument provides data of particle measurements in CDF format in three levels: Level0, Level1 and Level2. Level0 is the raw data from the instrument. Level1 is derived from Level0, which provides direction wise separated particle counts vs ADC channel. Level 2 is the energy-calibrated data, derived from Level1. The software for the same has been developed and tested with the simulated data. The T&E committee for this software has been formed. T&E test team is verifying the software and accordingly suggested changes are being incorporated. The Quick Look Display (QLD) software is also developed and tested with spacecraft data. This QLD software is developed with LabVIEW environment and will be installed in ISSDC for the immediate analysis of the data.

(S. K. Goyal, A. R. Patel, N. K. Tiwari, P. Sharma, J. Sebastian, A. Sarada, B. Dalal, S. Kumar, N. Singh, D. Painkra, T. Ladiya, M. Shanmugam, S. V. Vadawale, D. Chakrabarty, A. Sarkar, P. Janardhan, and ASPEX Team)

Flight readiness of Chandrayaan-3 ChaSTE Payload

A payload called Chandras Surface Thermophysical Experiment (ChaSTE) has been developed jointly by PRL, Ahmedabad and SPL/VSSC, Trivandrum to be flown on Chandrayaan-3 lander. ChaSTE aims to study the thermophysical properties of Lunar subsurface by deploying a 10 cm thermal probe. The experiment for Chandrayaan-3 is similar to the one developed for the Vikram lander on Chandryaan-2 mission. Functional tests were carried out on the front-end electronics card (developed by PRL) and the results show that the functional performance of the ChaSTE FE FM card is within the acceptable limits and the package has been cleared and further delivered to SPL/VSSC, Trivandrum, for integration, T&E and delivery of ChaSTE payload to the Chandrayaan-3 project (Figure 37). All the flight subsystems of ChaSTE Payload were integrated and tested (at SPL/VSSC). After successful completion of all the qualifications tests on the payload as per CH3 ETLS, ChaSTE payload

has been delivered to URSC clean room for further integration with the Chandrayaan-3 Lander. We have been continuously involved in all the integration and test activities of ChaSTE. Various tests were carried out on the spacecraft integrated payload - Disassembled Mode and Assembled Mode Integrated spacecraft tests (IST), Pre- and Post-Thermovac, Pre- and Post dynamic, and Mission scenario tests, at URSC, Bangalore. The health and performance of the payload monitored during all these tests was found to be satisfactory and demonstrated flight readiness. The flight-spare front-end electronics card of ChaSTE is also fabricated and delivered. Various laboratory experiments and modelling studies related to data interpretation and derivation of science from ChaSTE are underway at PRL.

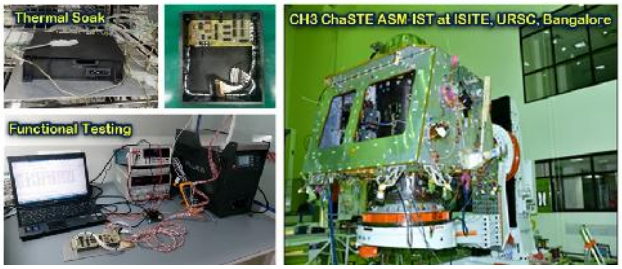

Figure 37: Functional verification tests of ChaSTE FE and Assembled mode Integrated Spacecraft Test (IST) of ChaSTE Payload

(K. Durga Prasad, Chandan Kumar, Sanjeev Mishra, P. Kalyan S. Reddy, Tinkal Ladiya, Arpit Patel, M. Shanmugam, Anil Bhardwaj and ChaSTE Team, SPL/VSSC)

Probe for PRATHIMA payload Lab Prototype design and evaluation

An experiment called Permittivity and Thermophysical Instrument for Moons Aquatic Scout (PRATHIMA) is being developed to be flown on ISRO-JAXA LUPEX (Lunar Polar Exploration) mission. The main objective of the proposed experiment is in-situ detection and quantification of water-ice mixed with lunar surface and sub-surface soil using a rover and lander platform using the technique of dielectric permittivity. Two important subsystems of this payload are the permittivity probe and a deployment mechanism. The permittivity probe consists of a set of four electrodes, two of which excite the surrounding medium using alternative sinusoidal current while the other two acquire the resultant voltage signals. Based on the amplitude and phase of the transmitted and received signals, probe factor and mixing models, water-ice mixed with the lunar soil is detected and quantified. As the arrangement of electrodes determines the vertical resolution, SNR, horizontal resolution and the accuracy of measurements, we have evaluated various configurations for the probe. After evaluating several configurations, a cylindrical probe with four annular ring electrodes are mounted at appropriate distances is realized (Figure 38). Lab experiments were carried out to examine the functionality of the probe, for unipolar and bipolar current excitation configurations, using a custom-developed experimental facility. These experiments were systematically carried out with pure water-ice samples, mixture of water-ice and sand, and pure sand samples. Qualitatively, no significant change in the output due to the two excitation scheme was seen. As the amplitude attenuation and the phase lag obtained in vacuum serves as reference for deriving the dielectric constant, the response of the probe under vacuum conditions was also investigated. Evaluation studies under different configurations are underway.

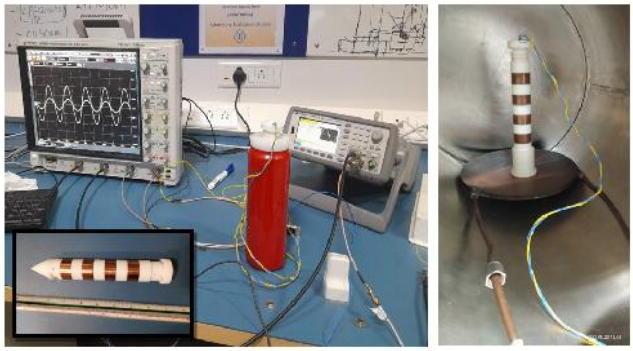

Figure 38: Experimental evaluation of PRATHIMA Probe prototype under ambient and vacuum conditions

(K. Durga Prasad, Sanjeev K. Mishra, Chandan Kumar, P. Kalyan Reddy, Janmejay Kumar, Tinkal Ladiya, Neeraj Srivastava, M. Bhatt, M. Shanmugam, Varun Sheel and Anil Bhardwaj)

Planetary Environmental Test Chamber (PETC) Prototype - Development and Testing

Considering a futuristic scenario, where there will be planetary missions with several instruments aimed for in situ atmospheric and surface science studies, a wide range of laboratory experiments under simulated environments are now indispensable. For this purpose, We have proposed to develop a large-scale Planetary Environment Test Chamber (PETC) at Physical Research Laboratory, Ahmedabad, which will serve as a useful multi-purpose facility for carrying out various experiments and tests related to planetary science and exploration (Figure 39). This is invaluable in conducting experiments with timescales of hours and simulating various planetary environments and surface test-beds. The establishment of a new chamber for simulating Planetary environments is envisaged because the chambers that are existing as of now are mostly thermo-vacuum chambers, and these cannot be modified to operate for environmental simulations. As per the suggestion provided by TEC review committee, this activity will be carried out in a phased manner and a startup/prototype chamber is proposed to be built in pre-Phase I to demonstrate the proof of concept. A small cylindrical prototype chamber with gas mixing system has been designed and fabricated in-house. The entire system was moved to a new lab designated for this activity. Unlike conventional gas-mixing systems, a cost-effective scheme using flow controllers has been devised and augmented to the system. Using this we were able to achieve the desired mixing pressures of gases inside the system. To measure the concentration of various gases, the system was fitted with a Residual Gas Analyser (RGA). We have established a unique two stage setup using RGA where it was designed to work at high vacuum to detect and measure the gases that are present in the Planetary chamber at pressures of the order of few torr. We have also augmented the chamber with an in-vacuum sample holder/base plate along with a heating and cooling recirculatory system that can be heated or cooled to a wide temperature range of -90°C to 200°C. This will help in the precise

temperature control of planetary environment simulated in the system. The entire system is currently undergoing test and evaluation after which experiments will be initiated.

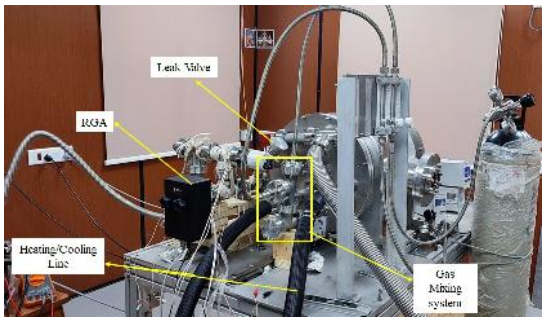

Figure 39: Prototype Planetary Environment Test Chamber and its subsystems

(K. Durga Prasad, P. K. Reddy and Janmejay Kumar)

Neutral & Ion Mass Spectrometer for the study of planetary atmospheres

Development of Quadrupole mass spectrometer for the measurements of neutral species and ambient ions is undergoing at PRL. This instrument called as Neutral & Ion Mass Spectrometer (NIMS) is being developed for a mass range of 2 200 amu (M/ΔM $>$10) for future planetary missions. The objective of the payload is to carry out the in-situ measurements of neutral species and ambient ions to characterize the planetary upper atmosphere and ionosphere. The CAD model of the NIMS is shown in Figure 40.

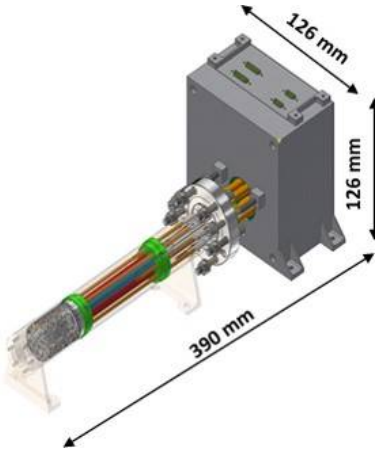

Figure 40: CAD model of the NIMS

NIMS works in two different modes viz. a) The Neutral Mode, which is used to measure neutral species by passing them through an ionizer, and b) The Ion mode, which is used to measure the positively-charged ambient ions. The incoming sample of gaseous species is further filtered based on the ratio of their mass to their charge (m/q). NIMS can be commanded to either sweep across a range of mass or allow only a species of interest to pass, by tuning the instrument to a fixed m/q value. The filtered species are then focused to the detector assembly (as shown in Figure 41) which consists of two types of detectors: Faraday Cup and Channel Electron Multiplier (CEM).

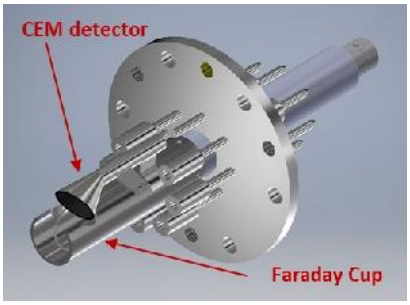

Figure 41: Detector assembly

Faraday Cup detector is used when there are sufficient number of species available (pressure range: 10^{-5} to 10^{-7} Torr) while CEM detector is used for higher vacuum. Photographic view of the CEM is shown in figure 42. The CEM detector requires biasing voltage, close to -2.5 kilo-Volts in order to enhance the signal (gain $\sim$1e6). The PCB has been designed and fabricated for the biasing of the CEM detector. The components used are commercial versions of the space qualified ones. The Sitael module along with the PCB is shown in Figure 43. Preliminary test results of high voltage circuit using Sitael module shows no degradation in the performance with different operating pressures. The interface of the PCB with the LabVIEW interface is undergoing as part of development of processing electronics of the instrument.

Figure 42: Channel Electron Multiplier (CEM)

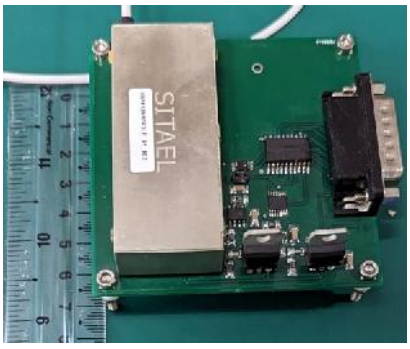

Figure 43: PCB for high voltage generation for the biasing of the CEM detector.

(P. Sharma, Abhishek Verma, Nirbhay Upadhyay, R.R. Mahajan, S. K. Goyal, Varun Sheel & NIMS team)

Geosciences

Model based examination of radiocarbon contribution from Indonesian throughflow to the south-eastern tropical Indian Ocean

Shallow seawater coral records from the south-eastern tropical Indian Ocean region were investigated to study Indonesian throughflow (ITF).

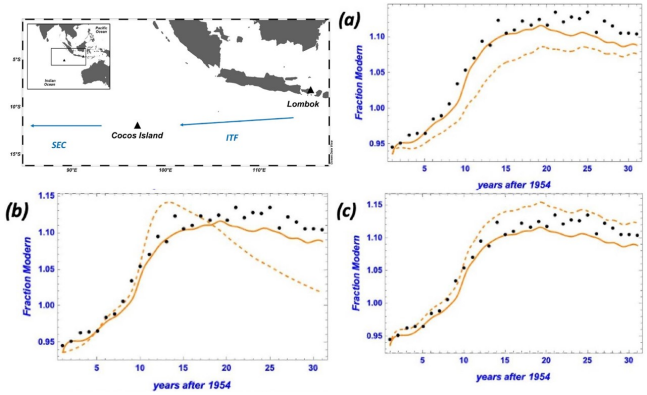

Figure No. 1: Filled circles are Cocos Islands coral radiocarbon record
Box model output (dashed lines) based on bomb-radiocarbon record for the years post-1954.

In this study, the radiocarbon records of Porites corals were used to estimate lateral transport via ITF and to understand the influence of ITF on radiocarbon levels in the surface waters in the south-eastern tropical Indian Ocean. A simple box model with radiocarbon was applied for this purpose. The model estimated a mean lateral transport via ITF of 12.5×106 m^3 s^{-1} towards the south-eastern tropical Indian Ocean region. The model was further used to reconstruct the post-bomb radiocarbon level in the Cocos Island surface water and the result was compared with the observed value. The box model result demonstrated that along with air-sea CO^2 exchange, the ITF was also an important contributor of bomb radiocarbon to the surface water of the south-eastern tropical Indian Ocean.

doi: https://doi.org/10.1016/j.jenvrad.2023.107165

(H. Raj, R. Bhushan & A. Narang)

Spatial heterogeneity in beryllium isotopic distribution in the Indian Ocean

Beryllium-10 (^{10}Be) has proven to be an important tool for building chronology and understanding millennial-scale surface processes. Measurements in both the water column and authigenic fractions from various archives (such as surface sediments and Fe-Mn crusts) have provided valuable information on processes regulating Be isotopic distribution in the global oceans. Unlike the Pacific and the Atlantic Oceans, Be isotopic measurements in the Indian Ocean are sparse. In this study, based on Be isotopic measurements on surface sediments from the central and northern Indian Ocean, an attempt is made to understand the processes controlling spatial Be isotopic distribution. Our data from the northern Indian Ocean indicates that terrestrial input is one of the primary contributors of ^{9}Be. Owing to higher terrestrial flux, the sediment samples from the Bay of Bengal show higher ^{9}Be concentrations and lower ^{10}Be/^{9}Be ratios. Our study also suggests that scavenging by sediment particles plays a vital role in the distribution of Be isotopes in well-mixed open ocean water. Between carbonates and clay particles, carbonates are less efficient in scavenging Be from the water column.

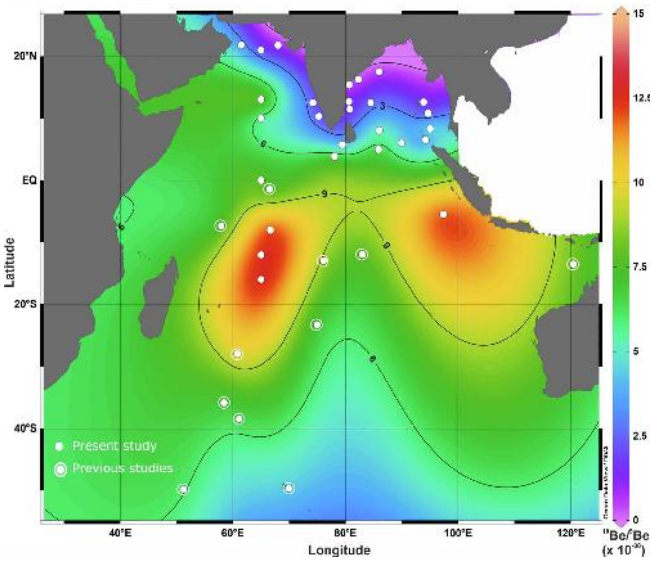

Figure No 2: Distribution of ^{10}Be/^{9}Be ratio (x 10^{-08}) in the deep-water column of the Indian Ocean. The values are derived from different archives, such as surface sediments (Bourles et al., 1989; present study) and Fe-Mn crusts (von Blanckenburg et al., 1996)

doi : https://doi.org/10.1016/j.gca.2022.12.009

(Partha S.J., R. Bhushan, A. Shivam & A.K. Sudheer)

Seasonal variation of surface seawater radiocarbon in the Andaman Sea as recorded in corals

Corals provide high-resolution radiocarbon record of the surface ocean which in turn help us to understand the surface ocean conditions and the regulating processes. A Porites coral from the Andaman Sea was investigated for its high-resolution radiocarbon record from 2007 to 2014 CE. The coral registers the seasonal changes in mixed layer depth and sea surface temperature between

the monsoon and non-monsoon periods.

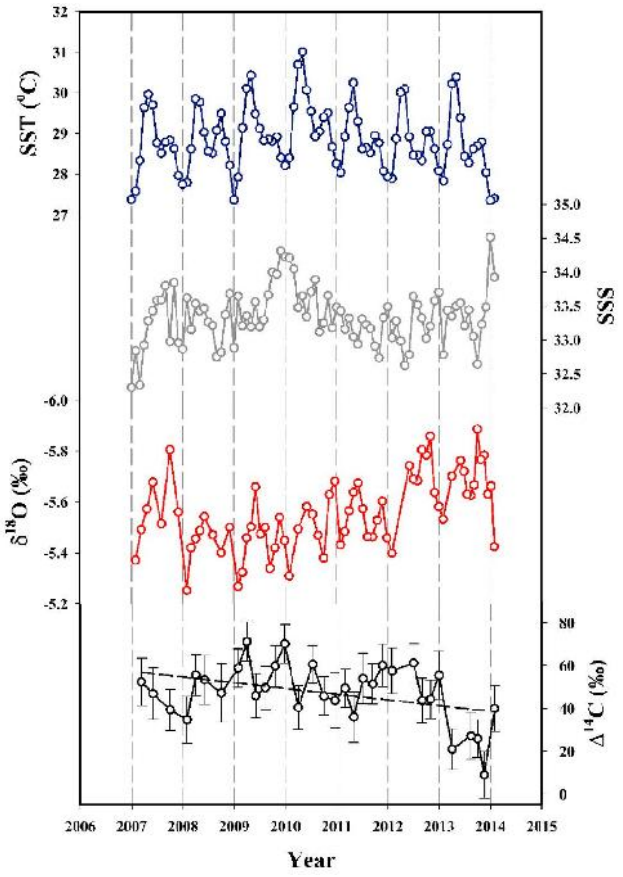

Figure No. 3a: Sea surface temperature (SST) record from 92-93°E 11-12°N (ERSSTv5, https://climexp.knmi.nl), sea surface salinity (SSS) record from 92.5°E 11.5°N (VAM MNT ARGO SSS, http://las.incois.gov.in) along with δ^{18}O and Δ^{14}C record of Chidiyatapu coral between 2007 and 2014.

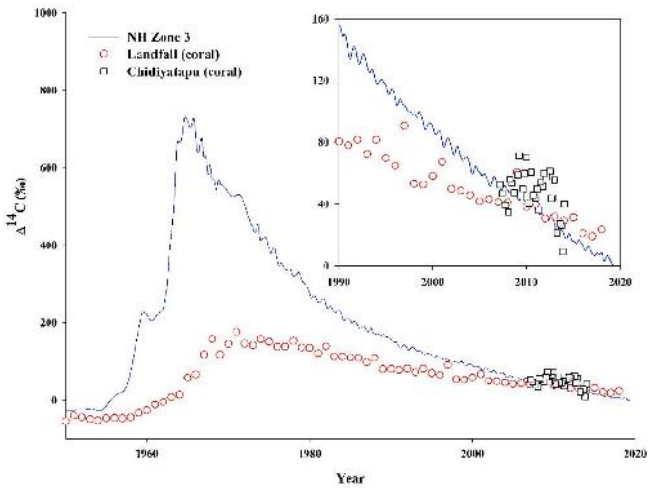

Figure No 3b:Comparison of the atmospheric Δ^{14}C record of NH Zone 3 (Hua et al., 2022) along with Indian Ocean coral Δ^{14}C record from Landfall (Raj and Bhushan, 2021) and Chidiyatapu in Andaman Island

We estimated a post-bomb period decline trend of 2.7 ‰yr^{-1} along with seasonal variations. A positive correlation is observed between the seasonal radiocarbon changes and the stable oxygen isotope ratio of the coral. Recent radiocarbon values of the Andaman Sea surface water have been found to be higher compared to the contemporary atmospheric radiocarbon values.

doi : https://doi.org/10.1016/j.jenvrad.2022.107021

(H. Raj, R. Bhushan, U.S. Banerji, Partha S.J. & A.J. Dabhi)

Relict proglacial lake of Spituk (Leh), northwest (NW) Himalaya: A repository of hydrological changes during Marine Isotopic Stage (MIS)-2

In the northwestern Himalaya (Ladakh and Karakoram), the spatial and temporal changes in the late Quaternary glaciation were modulated by combining two contrasting moisture sources (viz., the Indian Summer Monsoon and the mid-latitude westerlies).

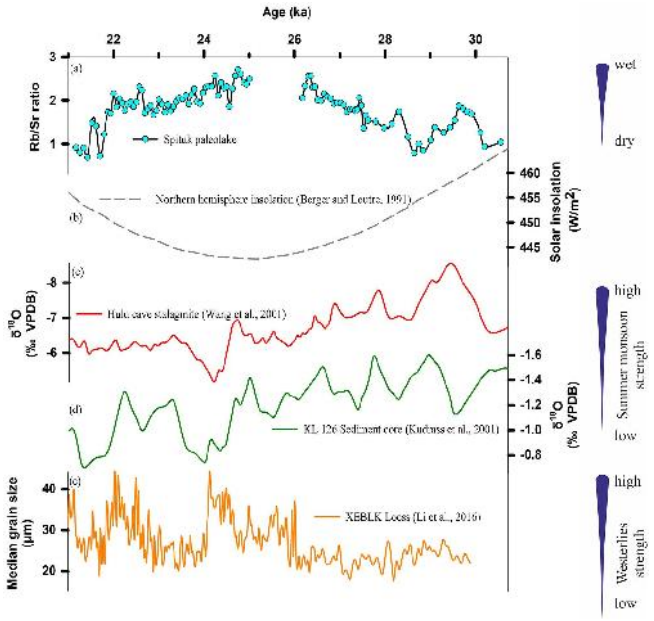

Figure No. 4: Spituk Lake deposit and the regional paleoclimate reconstruction. (a) The Rb/Sr ratio from Spituk paleolake is compared with (b) Northern hemisphere insolation, (c) δ^{18}O record of Hulu Cave stalagmite, (e) δ^{18}O record of foraminifera from a Bay of Bengal sediment core, (f) Grain size data from XEBLK loess.

The inferences about their relative contribution to glacier expansion are based on the ages obtained on moraines. Since the moraines suffer from poor preservation and chronological uncertainty, the present study, therefore, resorted to a near-continuous relict proglacial lake succession in order to reconstruct the continuous pattern of glacier fluctuations during Marine Isotopic Stage-2 (MIS-2). Since the AMS radiocarbon ages (both organic and inorganic matter) suffered from various complexities such as dead carbon contribution and hard water effect, the paleohydrological inferences in this study were drawn primarily based on optical ages (along with sedimentological and geochemical analysis). The proglacial lake sedimentation was modulated by the temporal changes in meltwater discharge. This is attributed to the waning and waxing of proximal valley glaciers. Evidence accrued from the lake sediment supported by the published

moraine chronology suggests that valley glaciers expanded during the onset of MIS-2 and persisted until around the Last Glacial Maximum (LGM). The beginning of MIS-2 is marked by the onset of cooling (∼30 ka), which led to a marginal advance in the glaciers. Additionally, early MIS-2 was characterised by millennial-scale climatic fluctuations. For example, a short-lived increase in humidity was observed between 30.2 ka and 29.3 ka, followed by a reversal towards a drier climate between 29.3 ka and 28.1 ka. During the early part of MIS-2, glaciers were driven by the decrease in temperature, whereas the enhanced moisture contribution during mid MIS-2 was responsible for extensive glacier growth. We hypothesise that the enhanced moisture was contributed by the mid-latitude westerlies, with subordinate contribution from the Indian Summer Monsoon (ISM). We attribute this to the southward positioning of the Intertropical Convergence Zone (ITCZ) during MIS-2.

doi : https://doi.org/10.1016/j.palaeo.2022.111164

(Partha S.J., R. Bhushan, H. Raj, A.J. Dabhi, S. Sharma, A.D. Shukla & N. Juyal)

Southern hemisphere forced millennial scale Indian summer monsoon variability during the late Pleistocene

Speleothems (stalactite and stalagmite), column shaped carbonate deposits growing in the dark galleries of limestone caves are important terrestrial archives of past environmental conditions.

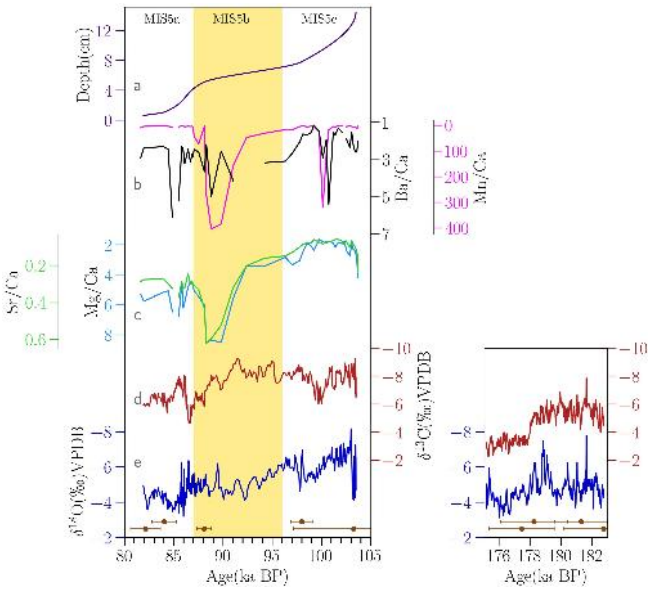

Figure No. 5: For the Belum stalagmite, (a) growth rate (cm/kyr) (b) Mn/Ca (pink) and Ba/Ca (black) (c) Sr/Ca (green) and Mg/Ca (light blue) trace element ratios are shown for the MIS-5 sub-stages. (d) δ^{13}C (red) and (e) δ^{18}O (blue) profiles. The ^{230}Th ages with 2σ errors are shown as filled circles (orange) and the stadial period MIS-5b is highlighted in yellow.

Indian Summer Monsoon (ISM) variation was reconstructed using a stalagmite from Belum cave, peninsular India. High-resolution stable isotope ratios (δ ^{18}O and δ ^{13}C) and trace element (Mg/Ca, Sr/Ca, Ba/Ca, Mn/Ca) data, spanning the glacial MIS-6 (from ∼183 ka to ∼175 ka) and interglacial sub-stages MIS-5c-5a (∼104 ka to ∼82 ka) showed significant variability in the past monsoon strength. On millennial timescale, during MIS-5b, we found that ISM variability did not follow Northern Hemisphere Solar Insolation at 30°N; instead, it was modulated by the cross-equatorial low-level Somali jets, whose strength was governed by the temperature gradient between subtropical southern hemisphere Mascarene high and Indian low. We investigated the role of the Southern Hemisphere processes in modulating monsoon strength as a part of the Hadley circulation. We identified several strong and weak episodes of ISM intensity during 104 to 82 kyr. Some of the weak episodes correspond to warming in the southern hemisphere were associated with weak cross-equatorial winds. We showed that during the MIS-5 sub-stages, ISM strength gradually declined with millennial scale variability linked to Southern Hemisphere temperature changes which in turn modulated the strength of the Mascarene High. We inferred that the cross-equatorial flow of moisture and resultant perturbation in ISM could have been a key transporter of the climate signal from the southern hemisphere to the northern hemisphere.

doi : https://doi.org/10.1038/s41598-022-14010-6

(M. G. Yadava)

New insights into diffusive kinetic fractionation during liquid condensation under supersaturated environment: an alternative approach for isotope tagging of ground-level water vapour

Stable water isotopes in ground-level vapour are key to estimating water exchange between geospheres. Their sampling, however, is limited to laser-absorption spectrometers and satellite observations, having inherent shortcomings. This study investigates diffusive kinetic fractionation during liquid condensation under supersaturated environment, providing a cost-effective, reliable way of sampling ground-level vapour isotopes (^{18}O, ^{2}H). Experiments were undertaken at three locations in India with 'liquid' samples collected from condensation of ambient air at 0°C. Simultaneously, pristine 'vapour' was sampled via cryogenic-trapping using liquid nitrogenalcohol slush at –78°C. The 'liquid' condensed under supersaturation was progressively more depleted in ^{18}O, and less enriched in ^{2}H than expected under equilibrium fractionation, with an increasing degree of supersaturation expressed as saturation index (Si). This study revealed: (1) Si, molecular density, Rh, T together control the extent of isotopic kinetic fractionation. (2) The presence of diffusive concentration gradient inhibits the flow of heavier isotopes during liquid condensation. (3) The stochastic nature of the process cannot be explained using a physics-based model alone. The artificial neural network model is hence deployed to sample δ ^{18}O (δ ^{2}H) within -0.24 $\pm$ 1.79 ‰(0.53 $\pm$ 11.23 ‰) of true value. (4) The approach can be extended to ground-validate isotope-enabled general circulation models and satellite observations.

doi : https://doi.org/10.1080/10256016.2022.2153126

(A. Ganguly, V. Padhya, H. Oza, & R.D. Deshpande)

Surface water-groundwater interaction in water-stressed semi-arid western India: Insights from environmental isotopes

Understanding the groundwater-surface water interactions and groundwater recharge mechanism is paramount in arid and semi-arid region which covers nearly 1/3rd of the continental area globally and depends on the groundwater to sustain ecology and livelihood of the people. One such region is semi-arid western India. This study uses seasonal isotopic (δ ^{18}O and d-excess) differences to study groundwater dynamics in semi-arid western India, in conjunction with the isotopic composition of India Summer Monsoon (ISM) to understand the rainfall - groundwater relationship, variation in recharge characteristics and quantification of groundwater recharge by rain. Some of the Important results of this study are (1) Temporal variation in the isotopic composition of shallow groundwater reveals that only ∼47% of the area is recharged by ISM rainfall; (2) Isotopic enrichment in post-monsoon season in certain regions (∼25%) indicates that deep static non-replenishable groundwater is extracted for irrigation, which finds its way into shallower aquifers; (3) ∼25% (0.52 Billion Cubic Meters) of the available dynamic groundwater resource in South Gujarat is lost as submarine groundwater discharges into the Arabian Sea; (4) Groundwater in the coastal area near the Gulf of Kachchh is recharged by hypersaline waters from salt pan.

doi : https://doi.org/10.1016/j.jaridenv.2022.104879

(A. Pandey, V. Padhya, A. Ganguly, S. Chakra & R.D. Deshpande)

Investigating hydrometeorology of the Western Himalayas: Insights from stable isotopes of water and meteorological parameters

The Himalayas govern the hydrometeorology of the entire Indian subcontinent and feed 19 major rivers on which a large population is dependent. Despite its vast socio-economic relevance, there exist knowledge gaps in the detailed understanding of Himalayan hydrometeorology. The present study attempts to understand subtle hydrometeorological processes concerning precipitation in Western Himalaya (WH), which is further complex due to several mountain ranges in addition to the Great Himalaya and varied land cover. In this backdrop, oxygen and hydrogen isotopic analyses of daily precipitation samples collected from Jammu was done. Major processes and features identified are: (1) Raindrop re-evaporation is dominant as indicated by lower δ^{18}O – δD regression slope (6.6 $\pm$ 0.2). (2) Maximum raindrop re-evaporation occurs during Western Disturbances (WD), evident from the low d-excess (<10 ‰) and high δ^{18}O (>0‰) with low rainfall. (3) Contrary to expectations, negligible moisture is derived from the Mediterranean region (MR) through WD. In contrast, maximum moisture (∼97%) is derived from local terrestrial sources, estimated through backward wind trajectories and confirmed by vertical wind velocity (ω) and OLR. (4) The Arabian Sea (AS) moisture contributes more (∼11%) compared to the Bay of Bengal (BOB) moisture (∼8%) during the monsoon. (5) Isotopically, the most depleted precipitation during July–Aug is associated with continental recycling from the Indo-Gangetic plains and not with the BOB moisture. (6) Isotopic enrichment in precipitation towards end of monsoon is attributed to raindrop re-evaporation, lesser rainout fraction and moisture derived from enriched local sources. (7) Annually, 87% of the moisture for precipitation is derived through continental recycling, and only 13% of the moisture is derived through marine sources (11% from AS and 2% from BOB). Moisture from MR (<0.1%) is negligible.

doi : https://doi.org/10.1016/j.atmosres.2021.105997

(H. Oza, V. Padhya, A. Ganguly & R.D. Deshpande)

Identifying and estimating the sources of river flow in the cold arid desert environment of Upper Indus River Basin (UIRB), western Himalayas.

A reliable water supply in different Himalayan River basins is increasingly important for domestic, agriculture, and hydropower generation. These water resources are under serious threat due to climate change, with the potential to alter the economic stability of 237 million people living in the Indus River Basin alone. In the present study, we used new stable water isotope data set to identify and estimate the different sources of streamflow and their controlling factors in the Upper Indus River Basin (UIRB), India. The data set presented wide spatial and temporal variability without the distinct isotopic signature of various sources of river flow. However, variable but distinct signatures of sources of river/stream flow exist at the sub-basin or catchment scale. These variabilities are ascribed to changing physiographical, meteorological, and local climatic conditions. Further, the distinct microclimatic conditions including altitudinal variability, aspect slope, etc. govern the spatio-temporal variability of sources and streamflow, hence different lapse rates at sub-basin/catchment scale. The study suggested that the contribution of snowmelt and glacier melt to river flow varies spatially and temporally. The Bayesian mixing model results suggested that snowmelt contribution is higher in Indus (63 $\pm$ 1.2%) and Shyok (58 $\pm$ 1.7%) while as, glacier melt contribution is higher in Nubra 64 $\pm$ 2.3% and Suru 60 $\pm$ 2.7% sub-basins/catchments. The groundwater contribution (baseflow) sustains and regulates the flow in rivers/streams during winter and spring, which is very vital for the local water supply. The study suggests that the spatially diverse rugged topography and microclimate in UIRB dominantly control the differential contribution from various sources of river flow. The warming climate, which has resulted in a decrease in solid precipitation, continuous glacier mass loss, early melting of snow cover, etc., would have an inconsistent impact on the perennial flow of rivers with the potential to alter the economic and political stability in the region.

doi : http://dx.doi.org/10.1016/j.scitotenv.2022.154964

(S. A. Lone, G. Jeelani, V. Padhya & R.D. Deshpande)

Extreme local recycling of moisture via wetlands and forests in NorthEast Indian subcontinent: a Mini-Amazon

Moisture recycling in precipitation is an important hydrological process, accounting for ∼67% globally. North-east India, home to the world's wettest place, boasts vast wetlands and forest-cover. Despite its proximity to the coast, we find locally recycled moisture to be the primary source of annual rainfall (∼45%). During the

pre-monsoon season, the enriched δ ^{18}O ($\sim$ -0.7‰) and high d-excess ($\sim$14 ‰) are ascribed to enhanced transpiration, owing to atmospheric instability which causes Nor'westers. During the Monsoon season, oceanic flux provides increased surficial moisture, enabling deep-localised convection via evaporation. Significant localised recycling, even during the monsoon season is estimated ($\sim$38%), with predominantly high d-excess in precipitation during latter half of the monsoon with increased moisture contribution from floods in Brahmaputra (high d-excess). The increasing δ ^{18}O and d-excess during the post-monsoon season is associated with progressively lesser rainout history and increased localized recycling ($\sim$67%). In light of the dwindling wetlands and forest cover, our study highlights their indispensable role in governing regional hydro-meteorology and water availability.

doi : https://doi.org/10.1038/s41598-023-27577-5

(A. Ganguly, H. Oza, V. Padhya, A. Pandey, S. Chakra & R.D. Deshpande)

Control of regional climate on carbon and nitrogen turnover in Indian soils

Stable isotopic analysis of carbon (C) and nitrogen (N) has helped to predict climate specific response of biological mediators of C and N cycles, and thus, turnover and availability of these elements in soils. However, application of general isotopic trends to soils of different ecosystems remains undetermined pertaining to inadequate data from vast eco-regions, including the Indian subcontinent. A study carried out at PRL focused on filling this data gap through isotopic analysis of soils from the arid, humid, and montane regions of India to understand the distribution and availability of total organic carbon (TOC) and total nitrogen (TN) under different temperature and precipitation conditions in an understudied tropical region. Results from the study for arid soils showed low TOC and TN contents with high δ^{13}C and δ^{15}N indicating active mineralization with limited organic matter supply. Contrarily, humid soils showed high concentrations of TOC and TN with low δ^{13}C and δ^{15}N indicating conservative N cycle. Isotopic signatures of montane soils showed spread over both arid and humid soils signifying higher control of edaphic factors over climate in the organic matter turnover in montane soils. Absence of climate specific isotopic pattern in the montane soils suggests careful application and interpretation of stable isotopic techniques in such regions. The results confirmed that even within a larger tropical setting, the regional climate regulate the elemental biogeochemistry and organic matter dynamics of soils.

doi : https://doi.org/10.1016/j.geodrs.2022.e00539

(N. Sharma and S. Kumar)

Fire and precipitation history of the Kashmir Himalaya during the last four thousand years

Throughout the human history, fire, climate, and human advancement had a very complicated relationship. Scientists have explored this relationship using different proxies such as black carbon, polycyclic aromatic hydrocarbons, and charcoal. To understand this complex relationship in the Himalaya, particularly in the Kashmir Himalaya, a region that was known as a gateway to India in the past, a study was undertaken using stable isotope ratios of black carbon (BC) in lake sediments. For this purpose, black carbon concentrations and its isotopic compositions in a sediment core retrieved from the Wular Lake, located in the Union Territory of Jammu and Kashmir, were measured. This core, dated using radiocarbon dating technique, covered the time span from 3752 to 306 cal years before present (BP). Results based on the relationship between mean annual precipitation and isotopic compositions of black carbon indicated two distinct climatic phases in the region. The first phase, during 3752–1500 Cal year BP, was characterized by low mean annual precipitation (dry climate), which transitioned into a wetter phase with higher mean annual precipitation after 1500 Cal year BP until 306 Cal year BP. Within the dry phase, a phase of extreme dryness and minimum precipitation around $\sim$2500 Cal years BP was observed. The variability in BC concentrations in the sediments revealed dynamic fire history in the Kashmir Himalaya with occurrences of high fire events around 3000 Cal years BP, which gradually declined until 1500 Cal year BP then increased again. These results, in combination with available studies from the region, suggested that forest fires in the Kashmir Himalaya were dominantly human-driven rather than due to large scale climate change.

doi : https://doi.org/10.1016/j.palaeo.2023.111401

(S. Verma, A. Rahman, M.G. Yadava, and S. Kumar)

Effect of tidal cycle on greenhouse gases

Atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have shown an abrupt increase of 47%, 156%, and 23%, respectively, since the industrial revolution. All three are principal greenhouse gases that contribute to about 90% of the forcing to anthropogenic climate warming, with significant contributions from estuaries and shallow coastal areas. Estuarine ecosystems, situated at the land-sea interface, receive large inputs of carbon and nitrogen from rivers and are important for transport and transformation of the continental carbon and nitrogen to the adjoining coastal ocean. One important characteristics of estuarine region is tidal cycle. But, how the tidal cycle affects the fluxes and concentrations of above-mentioned greenhouse gases is not very well understood, particularly in tropical setting. A study was carried out by PRL to understand the effect of tidal cycling on greenhouse gases based on six-hourly sampling for nine consecutive days at three locations along the salinity gradient in the Mahanadi estuary. The results obtained through this study revealed that the tidal forcing affected CO_2 and CH_4 in the mixing zone with elevated concentrations during low tide. Concentration of CO_2 increased with decrease in tidal height within low and high tide duration as well, possibly due to higher relative contribution of freshwater with high CO_2. N_2O, on the other hand, showed no significant variability with tidal cycle or water level fluctuation during high and low tide. Barring the offshore region, the study area was a source of greenhouse gases to the atmosphere.

doi : https://doi.org/10.1016/j.marpolbul.2023.114733

This work was conducted in collaboration with INCOIS, Hyderabad and NRSC, Hyderabad.

(M. Atif Khan and S. Kumar)

Nitrous oxide in the central Bay of Bengal

Although oceans contribute significantly to the global nitrous oxide (N_2O) emissions, there are less than desired data related to N_2O concentrations and fluxes in the global oceans and, in particular, the Indian Ocean. Within the Indian Ocean, the quantification and understanding of N_2O dynamics in the open Bay of Bengal (BOB) is lacking, specifically during the southwest monsoon. A study carried out at PRL focused on quantifying the dissolved N_2O concentrations in the water column along with water-atmosphere fluxes of N_2O from the central Bay of Bengal during peak monsoon. For this purpose, dissolved N_2O concentrations were measured from the surface to 2000 m depth at eight stations. The concentrations of dissolved N_2O in the surface waters ranged from 4.93 to 6.33 nM with saturation levels varying from 81 to 108%. Dissolved N_2O showed a small variation with depth and appeared to be undersaturated at all depths except at the surface and at the depth of deep chlorophyll maximum. Flux calculations revealed that out of eight, four stations acted as a minor source, whereas the rest were minor sinks for N_2O. The low concentrations of surface N_2O and small vertical gradients of N_2O in the water column suggested either low production of N_2O or significant consumption in the water column. Comparison of the present data with available studies in the coastal BOB suggested significantly lower concentrations and fluxes of N_2O in the open BOB. However, the range reported during the present study is closer to the only study carried out in the central BOB around twenty years ago; suggesting that N_2O dynamics in the BOB have not changed drastically in recent times.

doi : https://doi.org/10.1016/j.rsma.2022.102314

(M. Atif Khan, A. Singh and S. Kumar)

Oxidative Potential and Hydroxyl Radical Generation Capacity of Ambient $PM_{2.5}$ over a High-Altitude Site in Northeastern Himalaya: Role of Long-Range Transport

This study investigates the dithiothreitol (DTT)-based oxidative potential (OP) and corresponding hydroxyl radical (•OH) generation capacity of $PM_{2.5}$ (particulate matter with aerodynamic diameter smaller than 2.5 μm) over a high-altitude site, Shillong (25.7°N, 91.9°E; 1064 m above mean sea level), located in the northeastern Himalaya. Measured OP and •OH are reported in two units: per m^3 of filtered air (OP_V and OH_V) or per unit mass of $PM_{2.5}$ in μg (OP_M and OH_M). Based on the characteristic ratios of chemical species in different sources, $PM_{2.5}$ were classified into three source categories: Biomass Burning (BB), Secondary Organic Aerosols (SOA), and Mixed. Consistently higher OP and •OH generation per m^3 air in all BB-dominated $PM_{2.5}$ samples indicate relatively hazardous exposure dose from BB emissions among all sources. Characteristic OC/EC, WSOC/OC, and nss-K^+/EC ratios evoked that SOA from biogenic precursors was a significant source for the observed OP and •OH in SOA-categorized samples. Distinctly different chemical composition of $PM_{2.5}$ over Shillong (about 55% composed of organic matter) makes it relatively more (2 to 4 times) intrinsically redox-active compared to a reported study over another high-altitude site in India. Despite ~1.7 times lower $PM_{2.5}$ mass over Shillong (characterized by more aged $PM_{2.5}$) compare to Patiala (30.3°N, 76.4°E; 250m amsl, a semi-urban city, characterized by fresher $PM_{2.5}$ from mixed sources), the observed OP_V over Shillong was about 1.2 times higher, and the OP_M was about 2 times higher. It is attributed to the effect of atmospheric processing on particle's redox-activity during transport. While examining the relationship of OP_V and OH_V with chemical species, it was observed that •OH generation capacity was more influenced by the origin of WSOC (primary or secondary). Such an observation restricts the practicality of particle-induced OP to be considered as the only metric for aerosol particle toxicity, and suggests also to consider simultaneous measurements of •OH generations. Such studies are important for identifying redox-active aerosol species and developing appropriate mitigation policies for healthy air.

This study was carried out in collaboration with Arup Borgohain and Shyam S Kundu from NE-SAC

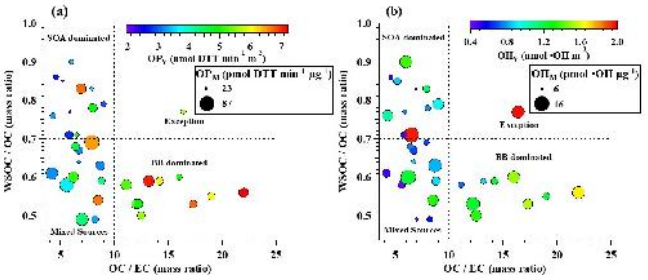

Figure No. 6: Scatter plots between OC/EC and WSOC/OC ratios, in which the color scale and bubble size show (a) OP_V and OP_M, respectively, and (b) OHV and OHM, respectively.

doi : https://doi.org/10.1016/j.atmosenv.2022.119263

(A. Patel, N. Rastogi, S. Rangu, and J. Dave)

Characterization of paddy-residue burning derived carbonaceous aerosols using dual carbon isotopes

A large scale paddy-residue burning (PRB) happens every year in the northwest Indo-Gangetic Plain (IGP) during the post-monsoon season, and winds transport pollutants from the source region up to the northern Indian Ocean affecting air quality of the IGP and marine region. In this study, day-night pairs of fine aerosol samples (n=69) were collected during OctoberNovember over Patiala (30.2°N, 76.3°E, 250 m amsl), a site located in the source region of PRB. Carbonaceous aerosols (CA) were characterised using chemical species and dual carbon isotopes (^{13}C and ^{14}C) to estimate bio vs non-bio contributions and understand their characteristics. Percentage of bio fraction (fbio, estimated using ^{14}C) in CA varied from 74% to 87% (avg: 80±3) during days and 71% to 96% (avg: 85±7 %) during nights. The $\delta^{13}C$ varied from -27.7‰to -26.0 ‰(avg: -27.0±0.4 ‰) and -28.7 ‰to -26.4 ‰(avg: -27.5±0.7 ‰) during day and night, respectively. Measured $\delta^{13}C$ of the samples was found to be higher by 0.3 to 2.0 ‰than expected, indicating the presence of aged CA also in Patiala even during PRB period. From fbio versus $\delta^{13}C$ correlation, and from Miller-Trans plot, $\delta^{13}C$ of PRB is found to be -28.9±1.1 ‰, which also infers that Miller-Trans plot can be used to understand source isotopic signature in the absence of radiocarbon measurements in aerosols. Further, the characteristics ratios of organic carbon (OC) to elemental carbon (EC) (11.9±4.1),

LG to potassium (K+) (0.84±0.15), OC/LG (19.7±2.0) and K+/EC (0.75±0.27) were calculated by considering samples with fbio higher than 0.90, which can be used for source apportionment studies. Such studies are crucial in assessing the effects of PRB on regional air quality and climate.

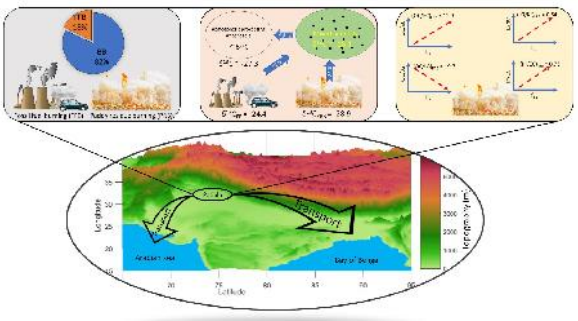

Figure No. 7: A cartoon depicting the major outputs from this study

doi : https://doi.org/10.1016/j.scitotenv.2022.161044

(M. Devaprasad, N. Rastogi, R. Satish, A. Patel, A. Singh, A. Dabhi, A. Shivam, R. Bhushan, and R. Meena)

Climatic history from valley-fill deposits from mainland Kachchh, western India

The arid landscape of the Kachchh region fosters several ephemeral fluvial systems which are susceptible to the complex interplay between tectonics and climate. The Indian Summer Monsoon (ISM) intensity plays a major role in the depositional phases of these ephemeral river systems. Temporal changes in the pattern of fluvial aggradation indicate that the fluvial systems have actively responded to ISM variations. The occurrence of valley-fill deposits throughout the region also signifies a phase of tectonic stability in contrast to the current regime which is dominated by incision activity. An attempt was made to understand the aggradation of sediments as valley-fill deposits in these ephemeral river basins. Employing the sedimentological, chronometric, and geochemical analysis on the fluvial terrace sequences of Nirona and Bhukhi river we tried to build up the climatic changes in the Weichselian period (12275 ka), which is analogous to the Marine Isotope stages (MIS) 5E, 5D, 5C, 5B, and 5A. The major objective was to reconstruct the temporal changes in ISM intensity during the Weichselian period in the Kachchh region and associated fluvial response to tectonic factors. A key inference from the present work is that variations in ISM intensity during MIS 5D-C have played a vital role in creating the sedimentary architecture of the study area in tandem with the prevailing tectonic forces.

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This work was carried out in collaboration with Dr. Subhash Bhandari, Professor, K.S.K.V. Kachchh University, Bhuj.

(N. Chauhan and A.D. Shukla)

Mid-late Holocene climatic reconstruction from coastal dunes of the western Kachchh, India

The coastal dunes which are associated with the coastal landforms are results of the sea-level fluctuations and its formation is the interplay of sediment supply, wind regime, tectonic, and nearshore hydraulic conditions. These deposits have been argued to be associated with both the regressive and transgressive phases of the sea water. During the transgressive sea regimes, the coastal dunes formed due to the high rate of sediment supply, while in regressive phase sea exposes the shelf providing space for accommodation and aggradation. To determine if the dunes along the coastline are formed due to transgression or regression, it is important to know the dune morphology. In this study we focus on the mechanism, climate, and sea-level implications of the coastal dune building activity in the eastern coast of Kori Creek (Gulf of Kachchh). The study area is crucial because the site responds well to climate changes, tectonics, Indus sediment flux discharge, and sea-level. Around 10 m thick dune is investigated using sedimentology, geochemistry, and optical chronology. This study suggests that the dune sediment that overlies the Tertiary Oyster Bed is 4 kyr old. The grain size analysis and correlation of textural parameters of the inland dunes and coastal dunes showed no stark difference, revealing they were deposited during the same time. Further, the geochemical data generated from the samples of the coastal dune site represent semi-arid to semi-humid climate with increasing chemical maturity and weakening monsoon during the time of deposition. Based on the current erosion dune face and optical ages of the samples, it can be related that the Kachchh coastline was exposed due to the lowering of the sea level at the time of the deposition of coastal dunes. The sea must be at a lower level to attain a preferable condition for the deposition of dunal landforms. The lowering of the sea exposed the beach with sandy material, which got blown away in strong wind, leading to dunes deposition. The cold phase at 4.2ka became the most conducive environment of coastal dune formation.

doi : https://doi.org/10.1016/j.quaint.2021.09.011

This work was carried out in collaboration with Dr. Subhash Bhandari, Professor, K.S.K.V. Kachchh University, Bhuj.

(N. Chauhan and A.D. Shukla)

Seasonal variability in aerosol water content and estimated pH over a coastal region in the Northeast Arabian Sea

The acidity of atmospheric particles can affect chemical processes thereby influencing secondary aerosol formation, the optical and water absorption characteristics of particles, and enhance trace metal solubility that can function as essential nutrients in nutrient-limited environments. In this study, estimated pH of ne particulate matter (FPM) through a thermodynamic model and assessment of its temporal variability over a coastal location in the northeast Arabian Sea are presented. Here, we have used the chemical composition of FPM (PM2.5) collected during the period 20172019. Chemical composition data showed large variability in water-soluble ionic concentrations (WSIC; range: 2.339.9gm3) with higher and lower average values during the winter and summer months, respectively. SO42 ions were predominant among anions, while NH4+ was a major contributor among cations throughout the season. The estimated pH of FPM is largely regulated by SO42 content and strongly depends on

the ambient relative humidity. Major sources of FPM assessed based on Positive matrix factorization (PMF) and air-mass back trajectory analyses demonstrate the dominance of natural sources (sea salt and dust) during summer months, anthropogenic sources in winter months and mixed sources during the post-monsoon season.

doi : 10.3390/atmos14020259

This work was done in collaboration with Dr. Ashwini Kumar, CSIR-NIO

(A.K. Sudheer)

Assessment of aeolian dust concentration, elemental composition and their wet and dry deposition fluxes over the north Arabian Sea

Atmospheric aerosol over the Arabian Sea is significantly impacted by the long-range transported mineral dust from the surrounding continents. This transported mineral dust is hypothesized and tested during several studies to see the impacts on the surface ocean biogeochemical processes and subsequently to the Carbon cycle. It is, thus important to quantify dust contributions and their fluxes to the Arabian Sea. We assessed the temporal variability of dust concentration, their elemental characteristics as well as quantify their dry and wet deposition fluxes over the North-eastern Arabian Sea. The dust concentrations were found to vary from 59 to 132 μg m^{-3} which accounts for 50% to 90% of total mass during dusty days. However, its contribution during pre and post dust storms ranges between 6% and 60%. Relatively higher dust dry deposition flux of 28$\pm$7 mg m^{-2} day^{-1} (range: 20–44) is estimated for dusty days compared to pre and post dusty days (range: 0.4–22 mg m^{-2} day^{-1}). In contrast to dry deposition fluxes, significantly higher fluxes are estimated from wet deposition, averaging around 240$\pm$220 mg m^{-2} day^{-1}. These values are five times higher than those reported from cruise samples collected over the Arabian Sea. Our estimation of dust flux over this region has implications for the supply of nutrients associated with natural dust to the surface water of the Arabian Sea.

doi : https://doi.org/10.1080/10962247.2022.2100509

This work was done in collaboration with Dr. Ashwini Kumar, CSIR-NIO, Goa

(K. Suresh and A.K. Sudheer)

Contribution of Carbon Fixation Toward Carbon Sink in the Ocean Twilight Zone

Like photosynthetic marine organisms, chemosynthetic organisms are also capable of converting atmospheric carbon dioxide gas to their organic matter—a process called carbon (C) fixation. While C fixation in the sunlit ocean is well explored, the C fixation potential of the twilight zone (water column from 100 to 1,000 m depth) harboring a diverse and rich assemblage of chemoautotrophs, remains largely unassessed. Within the twilight zone, the low oxygen waters might be a potential site for carbon dioxide assimilation as they possess abundant and diversified chemoautotrophs.

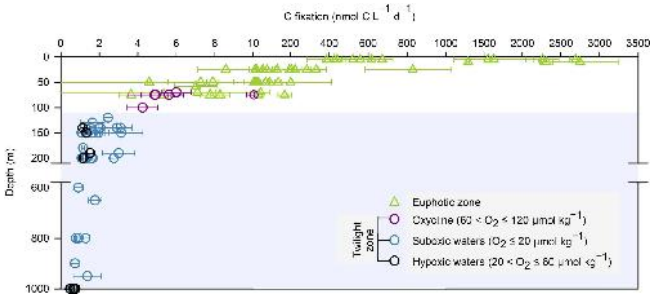

Figure No. 8: Vertical profile of C fixation rates in the euphotic and twilight zones. Shaded background indicates the oxygen minimum zone within the twilight zone. Note the break in the y-axis between 200 and 600 m.

We estimated C fixation rates in the euphotic and twilight zone of the Arabian Sea, which possesses one of the most intense and largest low oxygen zones of the global ocean (Fig. 8). We observed that average C fixation rates in the severely low oxygen waters were higher than that in the mildly low oxygen waters. Our results suggest that C fixation in the global ocean twilight zone contributes up to 7.4 Pg C y^{-1}. Thus, this study provides quantitative evidence to include twilight zone C fixation rates in the marine C budget estimates.

doi : https://doi.org/10.1029/2022GL099044

(H. Saxena, D. Sahoo, S. Nazirahmed, D.K. Rai, M. Atif Khan, N. Sharma, S. Kumar & A. Singh)

Convective mixing and transport of the Bay of Bengal water stir the δ^{18}O-salinity relation in the Arabian Sea

Stable isotopes are widely used to understand contemporary ocean processes and reconstruct palaeoclimates. Here, we present the distribution of oxygen and hydrogen stable isotope ratios (δ^{18}O and δD) in the Arabian Sea to understand their vertical profiles and establish a regional δ^{18}O-salinity (δ^{18}O-S) relationship. A large number (n = 102) of depth-specific water samples were collected along the latitudinal transect (65°E) in April 2017. Our results show significant surface variability in the isotopic composition of seawater with relatively ^{18}O-depleted water over the southern and ^{18}O-enriched water over the northern Arabian Sea. Surprisingly, there was no relationship between δ^{18}O and S in the surface waters. This no-relationship has implications in palaeoclimate reconstruction wherein we assume a linear δ^{18}O-S relation. However, data from the entire water column sampled (0-1000 m) showed a strong relationship with δ^{18}O = 0.35($\pm$0.03) S 11.84($\pm$1.12) (r = 0.79, p$<$0.05) and δD = (5.71 $\pm$ 0.80) δ^{18}O (0.66 $\pm$ 0.61) (r = 0.64, p$<$0.05). We propose that the surface δ^{18}O-S relationship is disturbed by the winter monsoon driven convective mixing and low salinity (and low δ^{18}O) water intrusion from the Bay of Bengal to the southern Arabian Sea. Strong δ^{18}OS relations were observed for distinct water masses, however, the water masses could not be distinguished based on their isotopic signatures alone. The slope of the δ^{18}OS relation was lower in the Arabian Sea High Saline Water compared to that in the Persian Gulf Water. A weak negative δ^{18}OS relation is observed for the Red Sea Water mass. The water masses were further verified using a temperature-salinity (T-S) diagram. At each station, the δ^{18}OS relationships of the vertical profiles were distinct, with

increasing slope and decreasing intercept from the south to north direction. Overall, surface water evaporation and vertical mixing over the northern Arabian Sea and freshwater intrusion from the Bay of Bengal in the southern Arabian Sea control the δ^{18}OS relationship in this region.

doi : https://doi.org/10.1016/j.jmarsys.2022.103842

(P. Kiran Kumar, A. Singh & R. Ramesh)

New constraints of terrestrial and oceanic global gross primary productions from the triple oxygen isotopic composition of atmospheric CO_2 and O_2

Through the nature of intimate coupling of global carbon and oxygen cycles via O_2 and CO_2 and their unique triple oxygen isotope compositions ($\Delta^{1}7$O) in the biosphere and atmosphere, we tried to estimate global CO_2 recycling with $\Delta^{1}7$O data over a large geographical coverage. We estimated global CO_2 recycling time of 1.5$\pm$0.2 year and gross primary productivities of $\sim$170200 PgC/year and $\sim$90-120 PgC/year by terrestrial and oceanic biospheres, respectively. We observed that the seasonal cycles between the east and west Pacific Ocean were different. This intra-annual variability implies that the entire atmospheric CO_2 turnover time is not much longer than the tropospheric mixing time (less than$\sim$5 months). The new measurements, analyses, and incorporation of other global data sets allow development of an independent approach, providing a strong constraint to biogeochemical models.

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This work was carried out in collaboration with Academia Sinica Taiwan, CalTech, Hebrew University of Jerusalem and University of California, San Diego.

(A. H. Laskar)

Impact of suboxic/hypoxic water column conditions in the Arabian Sea on Mo isotopic composition (δ^{98}Mo) in Arabian Sea

Molybdenum is an interesting element both in terms of the biochemistry and geochemistry. As the most abundant transition metal in the ocean, Mo plays an important role in biological systems as it is required by enzymes in catalyzing various key reactions in the metabolism of C, S, and N. It also plays an important role in regulating several biogeochemical processes such as denitrification. In addition, Mo is used as an essential metal cofactor in several enzymatically catalyzed steps in the marine nitrogen cycle. Isotopic fractionation of Mo is dependent on the redox conditions, and hence its isotopic composition (δ^{98}Mo) has the potential to track past oceanic redox changes. Mo abundance and δ^{98}Mo of the reducing and denitrifying water column of the Arabian Sea were measured to investigate the impact of intense water column anoxia, denitrifying conditions and high biological productivity in the Arabian Sea on δ^{98}Mo of seawater. In spite of abundant presence of denitrifiers, diazotrophs, and cyanobacteria and very high biological productivity in the Arabian Sea surface waters during the sampling season, Mo uptake by microorganisms in the Arabian Sea seems to have insignificant effect in influencing the Mo and δ^{98}Mo in surface and sub-surface waters. This observation can be explained by the fact that the biological requirements of Mo are significantly smaller than the abundant Mo pool in the surface waters. Hence, no Mo isotopic fractionation is observed despite high biological productivity in the Arabian Sea. In addition, δ^{98}Mo of the Arabian Sea water column can also be influenced by remineralization of the sinking organic matter, thereby releasing a lighter Mo pool at intermediate water column depths ($\sim$200-800 m). However, the obtained data from the Arabian Sea, do not show any variation in Mo isotopic composition through the intermediate waters. These observations suggest that the remineralization of the sinking organic matter through the water column seems to have little or negligible effects on δ^{98}Mo of the Arabian Sea water column.

doi : https://doi.org/10.1016/j.gca.2022.03.010

(V. Goswami)

Mountain highway stability threading on the fragile terrain of upper Ganga catchment (Uttarakhand Himalaya), India

In recent times, to cater for the need of the fast-growing population in the Indian Himalaya Region (IHR), there is a significant increase in road construction including widening in the seismically active and monsoon-dominated upper Ganga catchment (Uttarakhand Himalaya). The sustainability of the Himalayan Roads lies in the early assessment of the risk posed by potential geohazards particularly, the slope instability caused due to the excavation of steep slopes. However, the inherent geological, geomorphological, ecological, and climate fragility of the terrain warrants critical scientific intervention for the roads to sustain the vagaries of nature. We investigated a few representative road segments in the upper Ganga catchment (Uttarakhand Himalaya) which are currently undergoing widening. Detailed field observations supported by remote sensing data indicate that prior to the major road widening project (pre-2018) the landslides occupied around $51\times103m^2$ area which increased to $350\times103m^2$ following the road widening in 2022. The increase in landslide area is attributed to the poor slope management along the geologically and structurally weak segment. The Persistent Scatterer Interferometric Synthetic Aperture Radar (PSInSAR) data indicate that the segments where maximum slope instability are observed are undergoing a high rate of surface deformation. The study, therefore, suggests that disaster-resilient roads in the Himalayas must account for the geological fragility with an emphasis on slope stability and its management.

doi : https://doi.org/10.1007/s11629-022-7496-1

(S.P. Sati, S. Sharma, G.C. Kothyari, M. Asim, Y.P. Sundriyal, K. Malik, A. Joshi, H. Dobhal, N. Rana, & Juyal, N)

Emergent interactive effects of climate change and contaminants in coastal and ocean ecosystems

The effects of climate change (CC) on contaminants and their potential consequences to marine ecosystem services and human wellbeing are of paramount importance, as they pose overlapping risks. Climate drivers, such as ocean warming, ocean deoxygenation, changes in circulation, ocean acidification, and extreme events interact with

trace metals, organic pollutants, excess nutrients, and radionuclides in a complex manner. Overall, the holistic consideration of the pollutants-climate change nexus has significant knowledge gaps, but will be important in understanding the fate, transport, speciation, bioavailability, toxicity, and inventories of contaminants. Greater focus on these uncertainties would facilitate improved predictions of future changes in the global biogeochemical cycling of contaminants and both human health and marine ecosystems.

Climate change is going to intensify and exacerbate extreme events (IPCC, 2021). Some of these changes are already happening, as seen in the unprecedented number and magnitude of extreme events of the last decade. Extreme events, such as floods, can promote the transport and translocation of chemical contaminants and plastics to large areas, exposing organisms to high concentrations of contaminants for an extended period, potentially causing more ecological adverse effects and health risks through various exposure routes, including bioaccumulation in the food web.

A general failure to achieve the integrated knowledge and management of human pressures on marine systems is increasing risks to the benefits that people draw from the ocean in terms of food security, material resources, human health and well-being, coastal safety, and the maintenance of key ecosystem functions. The scarce information on species and ecosystem-level threshold, tolerances, and tipping points for various CC drivers mean that predictions of risk, vulnerability, and responses are difficult to make, and confidence is low. This highlights the urgency for a better understanding of the synergies between contaminants and CC and the challenges to develop effective remediation and conservation of coastal and ocean ecosystems. A key step will be to compile global databases of empirical measurements and modelling information on the effects of CC on contaminants for better informed predictions of future impacts, to support ecosystem-based planning decisions, to identify where pressing mitigation efforts are most needed, to plan proactive and more preventive management practices, and to monitor progress towards sustainable management actions.

As a Member of the Group of Experts on Scientific Aspects of Marine Environmental Protection (GESAMP), systematic efforts are made to assess the effects of changes in ocean physics and chemistry on the speciation, cycling, fate, transport, and bioavailability of trace metals, organic pollutants, radionuclides, and nutrients and to identify knowledge gaps, make recommendations, and planning for future research directions.

doi : https://doi.org/10.3389/fmars.2022.936109

(M.M. Sarin)

Atomic, Molecular and Optical Physics

Multispectral athermal fading rate measurements of K-feldspar.

This study reports athermal fading rates in K-feldspar grains extracted from sediments of varied ages and provenances. Multiple combinations of stimulation and emission spectral regions were examined to identify an optimum combination that provides a luminescence signal with minimal athermal fading. Stimulation wavelengths used were IR (855 $\pm$ 33 nm), green (525 $\pm$ 30 nm), blue (470 $\pm$ 20 nm), and violet (405 $\pm$ 15 nm), and detection windows were broad-UV (260400 nm), narrow-UV (327353 nm), and blue (320520 nm). Athermal fading rates using a single stimulation and sequential double stimulation combinations were estimated. For single stimulation, the average fading rates (gAV) ranged from 6.6 to 7.9% per decade. Sequential double stimulation comprising post green-blue (pGB), post blue-violet (pBV), post blue-IR (pBIR), and post violet-IR (pVIR) gave fading rates ranging from 2.0 to 0.0% per decade. The minimum fading rate value gAV = 0.0 $\pm$ 0.1% per decade was obtained for pVIR stimulation, and this highlights it as a potential candidate for dating sediments such that the tedium and time of fading measurements can be minimized.

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This work is done in collaboration with Sachin Joshi, MSU Baroda.

(Monika Devi, Naveen Chauhan, Haresh Rajapara, A.K. Singhvi)

An Early Presence of Modern Human or Convergent Evolution ? A 247 ka Middle Palaeolithic Assemblage from Andhra Pradesh, India

The region of South Asia, located between the prepared core-based technologies in the west and simple core technologies in the east, is crucial in the modern human dispersal routes. The nature and chronology of initial modern human presence in the region and associated lithic technologies microlithic vs the Middle Palaeolithic prepared core technology are debated between the coastal and continental routes of dispersals. Recent research, however, has pushed back the antiquity of Middle Palaeolithic technology in the region to 385 $\pm$ 64 ka, suggesting the possibility of local innovation. However, the age mentioned above is isolated spatially and requires further studies to support the local innovation model. Our research in the Paleru river basin, Andhra Pradesh (SE India), have identified several Palaeolithic sites in a stratigraphic context. We present the results of a systematic examination at the Hanumanthunipadu (Andhra Pradesh) site, where the deepest of three geomorphologically distinct phases of the sedimentary sequence contained Palaeolithic artefacts. The fine-grained sediments in the sequence, p-IR-IRSL dated to $>$ 247 $\pm$ 32 ka, yielded Middle Palaeolithic artefacts that imply South Asian Middle Palaeolithic assemblages may be a part of local innovations that emerged from the preceding Late Acheulian technologies.

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This work is done in collaboration with Anil Devara, Prof. Ajith Prasad, V. Mahesh, and Z. Khan, MSU Baroda.

(Monika Devi and Naveen Chauhan)

Luminescence Dating and Bracketing Time of the Youngest Toba Tuff Deposits in the Quaternary Sediments of Purna Alluvial Basin, Central India

In this work we tried to established chronology of reworked Toba ash deposits at two location for Puran river basin. Normally, light gray to yellowish brown youngest Toba tuff (YTT) ash, preserved in the Quaternary sediments of India, have been used as a tool to know depositional and bracketing time of the same in the sediments through applications of luminescence dating to interpret age connotation of various geological events. Pre- and post-tephra sediments of YTT ash beds from Hudki and Sukali areas of Purna alluvial basin, Central India have been optically dated to interpret the depositional age and bracketing time of the tephra within sedimentary sequences. These sediments are yellowish brown, thinly bedded, laminated, silty clay and host laterally extend discontinued beds of 0.150.20 m thickness. The ash is light gray, fine grained and powdery in nature, massive to structureless and lacks any sign of retransportation and redeposition, hence, considered as primary in nature. Total four sediment samples, one each from pre- and post-tephra lithounits of both the localities have been dated through optically stimulated luminescence technique (OSL) equipped with single aliquot regenerative (SAR) procedure on the feldspar grains. It shows pre- and post-tephra ages of 57 $\pm$ 5 and 70 $\pm$ 4 ka respectively for Hudki and 66 $\pm$ 5 and 67 $\pm$ 4 ka for Sukali localities. These depositional ages suggest that the ash was bracketed within sediments thousands years after YTT eruption. It is correlatable with the previously reported depositional and absolute ages for the YTT ash from the localities of Ghoghara and Khuntheli, Son Valley; Tejpur, Madhumati River Basin and Jwalapuram, Jurreru Valley. These ages also provide an idea about the period of existence of biological communities represented by the remains of faunal and vegetational activities before and during settlement of the YTT ash in the basin area.

doi : https://doi.org/10.1007/s12583-020-1357-z

This work is done in collaboration with Ajab Singh, University of Malaya Malaysia and Prof. Ashok K. Srivastava, SGB Amravati University.

(N. Chauhan)

The dominant role of deglaciation in Late PleistoceneEarly Holocene sediment aggradation in the Upper Chenab valley, NW Himalaya.

Sediment transfer from the interiors of the Himalayas is complex because the archives are influenced by both glacial and monsoonal cycles. To deconvolve the coupling of glacial and monsoonal effects on sediment transfer processes, we investigate the Late PleistoceneHolocene sediment archive in the Upper Chenab Valley. Optically stimulated luminescence (OSL) ages from the archive indicate major aggradation during ca. 2010 ka. Isotopic fingerprinting using Sr-Nd isotopes in silt fractions together with clast counts in boulder-pebble fractions indicate a decreasing Higher Himalayan sediment flux in the archive with time. Decreasing clast size, increasing clast roundness, increasing matrix-to-clast ratio, and dominance of the Higher Himalayan sourcing unequivocally suggest strong glacial influence during the initial stages of the archive formation. This evidence also agrees with the existing retreat ages of glaciers in the Upper Chenab Valley. Results of our study also show that the upper parts of the archive contain significant fluvial sediment contribution from the Lesser Himalaya, which suggests an active role of the stronger Indian Summer Monsoon (ISM) in the region during the Early Holocene. The apparent decrease in sediment supply from the Higher Himalayan sources could have been due to longer source-to-sink transport in the Early Holocene and/or increased hillslope flux from Lesser Himalayan sources.

doi : https://doi.org/10.1017/qua.2022.57

This work is done in collaboration with Saptarshi Dey, Pritha Chakravarti, Anushka Vasishth, Vikrant Jain from IITGN; Milan Kumar Mahal and Jyotiranjan S. Ray, GSDN PRL.

(N. Chauhan)

East Antarctica ice sheet in Schirmacher Oasis, Central Dronning Maud Land, during the past 158 ka.

We have carried out a study in Schimacher Oasis, Antarctica ice sheets, and established the chronology of the recessional moraines. The varied geomorphic landforms along the coast of eastern Antarctica suggest that the most recent phase of ice retreat was spatially heterogeneous. Ice retreat here comprised; a thinning of the East Antarctic Ice Sheet (EAIS) by up to 500 m and the recession of the ice wall in kilometers. This retreat deposited moraines over the Schirmacher Oasis (SO) in central Dronning Maud Land with minimal reworking. The present study used optical dating of the recessional moraines to determine the timing of their final emplacement. Three phases of moraine deposition, during 158125 ka; 7650 ka, and 22 ka to present, were inferred. It is suggested that decreased sea surface temperatures and increased sea ice cover of the surrounding oceans limited the moisture supply and led to the retreat of the ice. By $\sim$35 ka the SO became ice-free and has remained so, ever since. The inference that the ice sheet in this region was moisture limited, implies that in a global warming context, this region may not contribute to an increase in sea level. Instead, a warming-induced increase in moisture supply may even add to ice cover in the region.

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This work is done in collaboration with Sandip Kumar Roy, GSI Nagpur; Prakash Kumar Shrivastava GSI, Aliganj; Rajesh Asthana, GSI, Patna and Syed Ali Imam Mujtaba, GSI Faridabad

(N. Chauhan and A. K. Singhvi)

Luminescence Dating of Quartz: A MATLAB-Based Program for Computation of SAR paleo-doses using natural sensitivity correction (NCF)

This study presents a MATLAB-based program to implement the natural sensitivity correction (NCF) for the assessment of single aliquot regeneration-based paleo-doses (Singhvi et al., 2011; Chauhan & Singhvi, 2019). Several software packages/spreadsheets are in use to calculate the SAR paleo-doses (Des) but do not offer the facility for such a correction. The user-friendly program presented here computes NCF-SAR paleo-doses (Des) and includes the errors in the measured NCF values. Monte-Carlo simulation was used to propagate the uncertainties in the paleo-doses from the NCF and uncertainties in curve fitting parameters.

doi : http://ancienttl.org/ATL_40-1_2022/ATL_40-1

(Rahul Kumar Kaushal, Naveen Chauhan, Ashok K. Singhvi)

Anisotropic spatial entanglement

The photon pairs generated through spontaneous parametric down-conversion (SPDC) possess strong correlations in their transverse position and momentum degrees of freedom. For such photon pairs, the transverse position correlation length depends on the crystal thickness and the pump wavelength. In contrast, the transverse momentum correlation length depends on the pump's beam waist and spatial coherence length. By controlling these parameters, it is possible to engineer spatial entanglement. Here, we utilize the circular asymmetry of the pump by using an elliptical-Gaussian beam to change the degree of entanglement in transverse directions, which we call anisotropic entanglement. We show the interrelation between the degree of anisotropic entanglement and the asymmetry in the beam width. In addition, we also show that for a highly asymmetric pump beam, the entanglement vanishes along the direction of the thinner beam width, while it remains intact in the direction of the broader beam width.

doi : https://doi.org/10.1016/j.physleta.2022.128583

(Satyajeet Patil, Shashi Prabhakar, Ayan Biswas, Ashok Kumar, R P Singh)

Observing polarizationorbital angular momentum entanglement duality

Duality in the entanglement of identical particles manifests that entanglement in only one variable can be revealed at a time. We demonstrate this using polarization and orbital angular momentum (OAM) variables of indistinguishable photons generated from parametric down-conversion. We show polarization entanglement by

sorting photons in even and odd OAM basis while sorting them in two orthogonal polarization modes reveals the OAM entanglement. Indistinguishable photons entangled in two variables could find applications in robust quantum communication, remote entanglement generation, and distributed quantum sensing.

doi : https://doi.org/10.1007/s11128-022-03815-z

(Nijil Lal, Sarika Mishra, Anju Rani, Anindya Banerji, Chithrabhanu Perumangatt, R P Singh)

BBM92 quantum key distribution over a free space dusty channel of 200 meters

Free-space quantum communication assumes importance as it is a precursor for satellite-based quantum communication needed for secure key distribution over longer distances. Prepare and measure quantum key distribution (QKD) protocols like BB84 consider the satellite as a trusted device, which is fraught with security threats looking at the current trend for satellite-based optical communication. Therefore, entanglement-based protocols must be preferred, so that one can consider the satellite as an untrusted device. The current work reports the effect of atmospheric aerosols on the key rate obtained with BBM92 QKD protocol, an entanglement-based QKD protocol over a 200 m distance, using an indigenous facility developed at Physical Research Laboratory (PRL), Ahmedabad, India. Our results show that the concentration and extinction coefficient of atmospheric aerosols plays a major role in influencing the observed sift key rate, and eventually, the secure key rate. Such experiments are important to validate the models to account for the atmospheric effects on the key rates achieved through satellite-based QKD.

doi : https://doi.org/10.1088/2040-8986/ac6f0b

(Sarika Mishra, Ayan Biswas, Satyajeet Patil, Pooja Chandravanshi, Vardaan Mongia, Tanya Sharma, Anju Rani, Shashi Prabhakar, S Ramachandran, R P Singh)

Indistinguishable photons

Photons are characterized by several physical properties, such as their momenta, frequency, and polarization. These properties can be combined together to define the “mode” of the associated electromagnetic field. Two photons are said to be “identical particles” when they cannot be discerned based on such properties. Quantum mechanics allows identical particles to lose their individuality completely and become truly indistinguishable. This property of indistinguishability gives rise to exclusive quantum phenomena such as two-particle interference. Photon indistinguishability is crucial in realizing many quantum information protocols. The article covers the concepts and applications related to indistinguishable photons.

doi : https://doi.org/10.1007/s11128-022-03815-z

(Nijil Lal, Sarika Mishra, R. P. Singh)

Speckle-based deep learning approach for classification of orbital angular momentum modes

We present a speckle-based deep learning approach for orbital angular momentum (OAM) mode classification. In this method, we have simulated the speckle fields of the LaguerreGauss (LG), HermiteGauss (HG), and superposition modes by multiplying these modes with a random phase function and then taking the Fourier transform. The intensity images of these speckle fields are fed to a convolutional neural network (CNN) for training a classification model that classifies modes with an accuracy $>$99%. We have trained and tested our method against the influence of atmospheric turbulence by training the models with perturbed LG, HG, and superposition modes and found that models are still able to classify modes with an accuracy $>$98%. We have also trained and tested our model with experimental speckle images of LG modes generated by three different ground glasses. We have achieved a maximum accuracy of 96% for the most robust case, where the model is trained with all simulated and experimental data. The novelty of the technique is that one can do the mode classification just by using a small portion of the speckle fields because speckle grains contain the information about the original mode, thus eliminating the need for capturing the whole modal field, which is modal-dependent.

doi : https://doi.org/10.1364/JOSAA.446352

This work was done in collaboration with Venugopal Raskatla, B. P. Singh, and Vijay Kumar from the Department of Physics, NIT Warangal

(Satyajeet Patil and R. P. Singh)

Dynamical charge inversion of polarization correlation vortex in a propagating vector speckle field

A study on first-order polarization correlation in propagating vector speckle fields is carried out. Vector speckle field, generated by scattering of Poincare beam, is propagated through a spherical and a cylindrical lens. The first-order polarization correlation is experimentally constructed from intensity images of vector speckle fields at various planes before and after the focal plane. We have shown with supporting experimental and simulation results that polarization correlation vortex experiences charge inversion while vector speckle field propagates through a cylindrical lens. The importance of this study relies on the fact that it provides insight into one of the important properties of light, i.e., the phase between the orthogonal polarization components, and how it evolves as the optical field propagates through various optical components. This study could find applications in optical data processing, imaging, sensing, speckle meteorology, phase unwrapping, optical communication, etc.

doi : http://doi.org/10.1088/2040-8986/ac675a

This work was done in collaboration with Himangi J Pandit and Vijay Kumar from the Department of Physics, NIT Warangal

(R P Singh)

Augmenting data security: physical unclonable functions for linear canonical transform-based cryptography

Ever-increasing demand for the Internet of Things (IoT) devices mandates voluminous data transfer over communication channels. In this context, securing private data, i.e., authenticating the authorized users to access sensitive (personal) information, becomes mandatory. Several mathematics-based security approaches (i.e., cryptography) have been demonstrated in the literature to secure systems and networks from malicious attacks. Henceforth, cryptographic algorithms play a vital role in the digitized era. In general, information that needs to be sent from a sender end is encrypted (i.e., input data is converted into an unreadable format) using secret keys. At the receiver end, by appropriately using the keys encoded information can be retrieved (without loss) and this process is known as decryption. Linear Canonical Transform (LCT)-based optical encryption system has been used to provide the keys and secure the information, however, lately, it has been found to be vulnerable.

One of the primary reasons for this is the predictable nature of the keys (i.e., simulated random keys) used in the encryption process. To alleviate this, in this work, we present a Physically Unclonable Function (PUF) for producing a robust encryption key for the digital implementations of any optical encoding systems. We present a technique utilizing the correlation function of the scattered perfect optical vortex (POV) beams to generate the encryption keys. To the best of our knowledge, this is the first report on utilizing a scattered POV for optical encryption systems. To validate the generated keys, the standard Linear Canonical Transform-based Double Random Phase Encoding (LCT-DRPE) technique is used. Experimental and simulation results validate the proposed key generation method as an effective alternative to the digital encryption keys.

doi : https://doi.org/10.1007/s00340-022-07901-z

This work is done in collaboration with Patnala Vanitha, Bhargavi Manupati, Inbarasan Muniraj, Satish Anamalamudi, and Gangi Reddy Salla from SRM UniversityAP, Amaravati

(R P Singh)

Higher-order photon statistics as a new tool to reveal hidden excited states in a plasmonic cavity

Among the best-known quantities obtainable from photon correlation measurements are the g(m) correlation functions. Here, we introduce a new procedure to evaluate these correlation functions based on higher-order factorial cumulants CF,m that integrate over the time dependence of the correlation functions, that is, summarize the available information at different time spans. In a systematic manner, the information content of higher-order correlation functions as well as the distribution of photon waiting times is taken into account. Our procedure greatly enhances the sensitivity for probing correlations and, moreover, is robust against a limited counting efficiency and time resolution in experiments. It can be applied even in case g(m) is not accessible at short time spans. We use the new evaluation scheme to analyze the photon emission of a plasmonic cavity coupled to a single quantum dot. We derive criteria that must hold if the system can be described by a generic JaynesCummings model. A violation of the criteria can be explained by the presence of an additional excited quantum dot state.

doi : https://doi.org/10.1021/acsphotonics.2c00375

This work is done in collaboration with Prof. Gilad Haran.

(Satyendra Nath Gupta)

Role of plasma temperature and electron number density on signal enhancement observed in nanoparticle-enhanced LIBS-

The present work aims to understand the signal enhancement observed in nanoparticle-enhanced LIBS (NELIBS) due to changes in the plasma parameters as a result of improved atomization and excitation. A systematic study on signal enhancements during NELIBS using simultaneous spectroscopy and imaging is investigated by varying the experimental parameters like particle size and laser fluence. We have observed similar enhancements in spectroscopy and imaging channels regardless of nanoparticle(NP) size at different laser fluences. Although the plume size in NELIBS was marginally more prominent than the LIBS at the same laser fluence, the corresponding intensity in NELIBS is significantly higher. This agrees with the hypothesis of efficient atomization and excitation of plasma in the case of NELIBS. Therefore, we performed a sensitivity analysis using a simulated LIBS signal to understand changes in experimentally observable plasma parameters (excitation temperature and electron number density) on signal enhancement. We have shown that the enhancements in the emission intensities of typically 1 orders of magnitude can be explained as a result of the change in electron number density and plasma temperature. A comparison of the expected enhancement due to this change with experimental observation for a Cu I line is also presented.

doi : https://doi.org/10.1088/2040-8986/ac5ed0

(Swetapuspa Soumyashree and Prashant Kumar)

N-graphene synthesized in astrochemical ices

This is the first experimental proof for the synthesis of graphene and graphene quantum dots at very low temperatures, $<$ 10 K, in analogs experiments simulating ism cold dust. Icy mantles of benzonitrile, a recently identified molecule in the ISM, were irradiated by vacuum ultraviolet photons and then gradually warmed to room temperature. The leftover residue from the chemical changes brought by irradiation was then analyzed using a high-resolution transmission electron microscope which led to the finding of graphene and graphene quantum dots. Our experimental result has three implications:
[1] Graphene can be present in cold ISM dust containing aromatic molecules.
[2] graphene quantum dots contribute to the ISM emission.
[3] graphene and graphene quantum dots contribute to Titans haze.

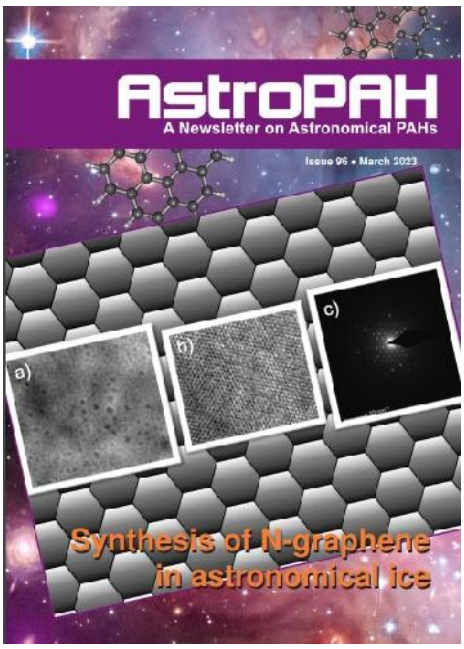

Figure no. 1: The cover page of the work that appeared in AstroPAH (Volume 96; 27 March 2023). The HR-TEM images of graphene and the diffraction pattern are shown.

doi : https://doi.org/10.1140/epjd/s10053-023-00590-z

(B Sivaraman, K K Rahul, M Ambresh, D Sahu, J K Meka, S L Chou, Y J Wu, D Gupta, A Das, J I Lo, B M Cheng, B N Rajasekhar, Anil Bhardwaj, H Hill, P Janardhan, and N J Mason)

Shock-induced transformation of non-magnetic to magnetic ISM dust analogue

The fate of organometallic dust subjected to extreme conditions, especially the shock fronts, in the interstellar medium (ISM) has not been explored to date.

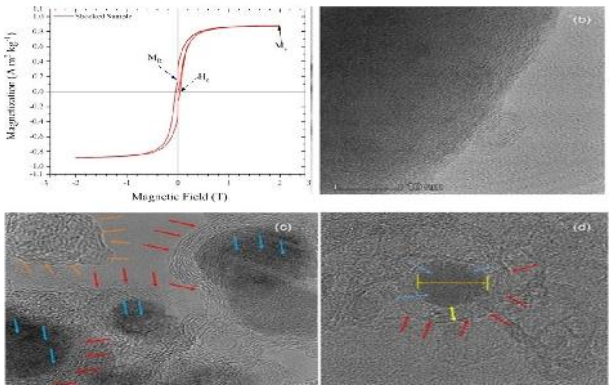

Figure no. 2: (a) The magnetization curve of the shocked sample was recorded using a VSM. (b - d) HR-TEM images of the shock-processed samples with different scales.

Iron and cyclopentadiene, which have been found to be present in the ISM, are known to react and produce the organometallic compound ferrocene under terrestrial conditions. In our experiment, we subjected ferrocene, a possible proxy of such dust, to ∼5.6 Mach (M) shock commensurate with conditions encountered in the ISM, leading to a temperature rise up to 7300 K within 2 ms. Analysis of the post-shock residue showed the presence of an α-Fe and Fe3C composite that responded to an external magnetic field. These results show that non-magnetic dust composed of molecules containing transition metals undergoing shock processing in the ISM can dissociate and synthesize dust that is then magnetic. Such drastic transformations from non-magnetic to magnetic dust induced by shocks might be important in interstellar polarization.

doi : https://doi.org/10.1093/mnras/stac2637

(Arijit Roy, Surendra V Singh, J K Meka, R Ramachandran, D Sahu, A Gautam, T Vijay, Jayaram Vishakantaiah, P Janardhan, B N Rajasekhar, Anil Bhardwaj, N J Mason, B Sivaraman)

Strong-field ionization of N_2 and CO molecules using two-color laser field:

In this study, we investigated the two-color strong-field photoionization of two diatomic molecules (N_2, CO) using a velocity map imaging (VMI) spectrometer. The fundamental frequency, along with the second harmonic (800 + 400 nm) at various phases, with the two different polarization schemes viz, orthogonal and parallel, is employed for measuring the yield of ions and photoelectron momentum distributions (PEMD).

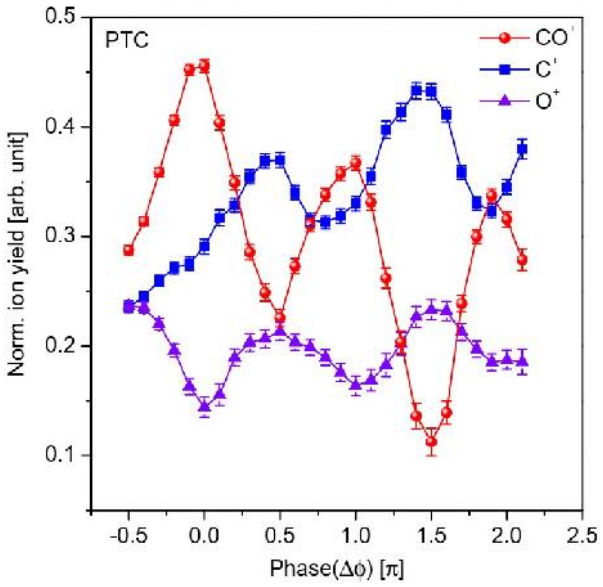

Figure no. 3: Normalized CO^+, C^+, and O^+ ion yield as a function of relative phase between SH and FW in units of degrees. This result was obtained using a two-color parallel polarized laser field with CO molecules.

The correlation trends of the parent ion with their fragments as a function of the two-color relative phase are investigated. In ionized N_2 and CO, we observed that the ionic fragments have different correlation trends with parent ion yield in both polarizations

(orthogonal and parallel) schemes. Additionally, the photoelectron momentum distribution of N_2 and CO due to orthogonal two-color (OTC) and parallel two-color (PTC) is performed in order to understand the modulation of tunnel electron dynamics as a function of phase between 800 nm and 400 nm. We observed that the two-color field modulates the tunnel electron trajectories and affects the photodissociative reaction's yield. This work demonstrates the Quantum control of molecular reaction using a two-color laser field. The yield of CO^+, C^+, O^+ as a function of relative phase is shown in Figure to demonstrate how two-color affects the dissociative reaction yield.

doi : https://doi.org10.1088/1361-6455/ac9873

(Madhusudhan P, Rituparna Das, Pranav Bhardwaj, Muhammed Shameem K M, Vinitha Nimma, Swetapuspa Soumyashree and Rajesh K Kushawaha)

ALMA Survey of Orion Planck Galactic Cold Clumps (ALMASOP): Density Structure of Centrally Concentrated Prestellar Cores from Multiscale Observations

Starless cores represent the initial stage of evolution toward (proto)star formation, and a subset of them, known as prestellar cores, with high density ($\sim 10^6 cm^{-3}$ or higher) and being centrally concentrated are expected to be embryos of (proto)stars. Determining the density profile of prestellar cores, therefore, provides an important opportunity to gauge the initial conditions of star formation. In this work, we perform rigorous modeling to estimate the density profiles of three nearly spherical prestellar cores among a sample of five highly dense cores detected by our recent observations. We employed multiscale observational data of the (sub)millimeter dust continuum emission, including those obtained by SCUBA-2 on the James Clerk Maxwell Telescope with a resolution of $\sim$ 5600 au and by multiple Atacama Large Millimeter/submillimeter Array observations with a resolution as high as $\sim$480 au. We are able to consistently reproduce the observed multiscale dust continuum images of the cores with a simple prescribed density profile, which bears an inner region of flat density and an r^{-2} profile toward the outer region. By utilizing the peak density and the size of the inner flat region as a proxy for the dynamical stage of the cores, we find that the three modeled cores are most likely unstable and prone to collapse. The sizes of the inner flat regions, as compact as $\sim$ 500 au, signify them as being the highly evolved prestellar cores rarely found to date.

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This work was done in collaboration with the ALMASOP international team.

(Dipen Sahu, Sheng-Yuan Liu, Doug Johnstone, Tie Liu, Neal J. Evans II, Naomi Hirano, Ken'ichi Tatematsu, et al.)

Strong-field ionization of CH_3Cl: proton migration and association:

In this study, we investigated the femtosecond laser pulses induced photoionization of CH_3Cl. The two-body dissociation of CH_3Cl^{2+} along H_n^+ (n = 13) and HCl^+ forming pathways, have been experimentally studied in a home-built COLTRIMS (cold target recoil ion momentum spectrometer) setup. The ionization rate (single) of CH_3Cl was obtained experimentally by varying the laser intensity from 1.6 10^{13} W cm^{-2} to 2.4 10^{14} W cm^{-2} and compared with the rate obtained using the MO-ADK model. Further, the yield of H_n^+ ions resulting from the dissociation of all charge states of CH_3Cl was determined as a function of intensity and pulse duration (and chirp). We observed that as a function of pulse duration (and chirp), the H_n^+ forming pathways were suppressed, while the HCl^+ forming pathway was enhanced. To understand the excited state dynamics of the CH_3Cl dication, which controls the outcome of dissociation, we obtained the total kinetic energy release distributions of the pathways and the two-dimensional coincidence momentum images and angular distributions of the fragments. We inferred that the H_n^+ forming pathways originate from the dissociation of CH_3Cl dications from weakly attractive metastable excited states having a long dissociation time, while for the HCl^+ forming pathway, the dication dissociates from repulsive states and therefore, undergoes rapid dissociation. Our study explains the mechanism of H_n^+ and HCl^+ formation and confirms that intensity and pulse duration can serve as parameters to influence the excited state dynamics and hence, the outcome of the two-body dissociation of CH_3Cl^{2+}. The enhancement in the yield of HCl^+ as a function of pulse duration is shown in Figure.

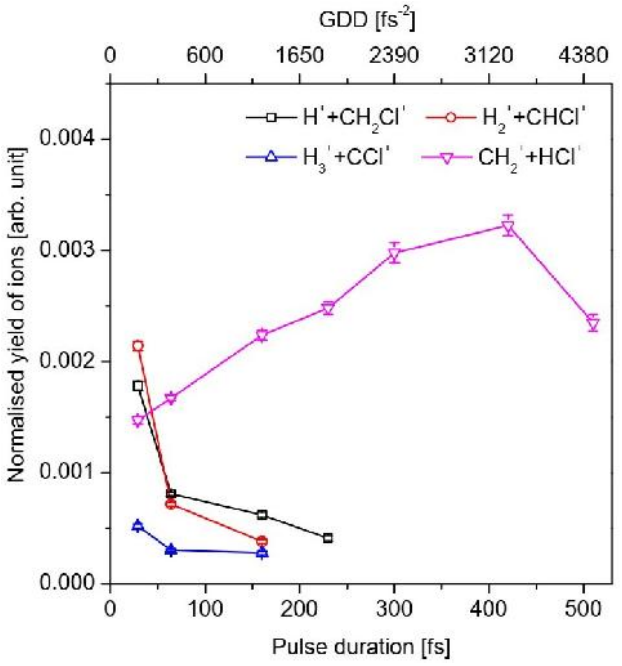

Figure no. 4: Normalized yields of four dissociation channels (shown in figure) as a function of pulse duration and chirp. The laser parameters like intensity (4.2 x 10^{13} W cm^{-2}), wavelength (800 nm), and polarization (linear) of the pulses were maintained constant throughout the measurements.

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The Theory work was done in collaberation with Dheeraj K Singh, IITRAM Ahmedabad.

(Rituparna Das, Deepak K Pandey, Swetapuspa Soumyashree, P Madhusudhan, Vinitha Nimma, Pranav Bhardwaj, Muhammed Shameem KM, Dheeraj K Singh, Rajesh Kumar Kushawaha)

Isotope Shifts in Cadmium as a Sensitive Probe for Physics Beyond the Standard Model

Isotope shifts (ISs) of atomic energy levels are sensitive probes of nuclear structure and new physics beyond the standard model. We present an analysis of the ISs of the cadmium atom (Cd I) and singly charged cadmium ion (Cd II). ISs of the 229nm, 326nm, 361nm, and 480nm lines of Cd I were measured with a variety of techniques; Burgas-cooled beam spectroscopy, capturing atoms in a magneto-optic-trap, and optical pumping. IS constants for the D1 and D2 lines of Cd II were calculated with high accuracy by employing analytical response relativistic coupled-cluster theory in the singles, doubles, and triples approximations. Combining the calculations for Cd II with experiments, we inferred IS constants for all low-lying transitions in Cd I. We benchmarked existing calculations via dierent many-body methods against these constants. Our calculations for Cd II enabled nuclear charge radii of Cd isotopes to be extracted with unprecedented accuracy. The combi- nation of our precise calculations and measurements showed that King plots for Cd I can improve the state-of-the-art sensitivity to a new heavy boson by up to two orders of magnitude.

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This work was done in collaboration with B. Ohayon of the Institute for Particle Physics and Astrophysics, ETH Zurich, CH-8093 Zrich, Switzerland; S Hofsss, J E Padilla-Castillo, S C Wright, G Meijer and S Truppe of Fritz- Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany; and K Gibble of Department of Physics, Pennsylvania State University, University Park, State College, PA 16802, USA.

(B. K. Sahoo)

Assessing slow-down times due to blackbody friction forces for high-precision experiments

We probed the roles of blackbody friction forces (BBFFs) in slowing down alkali atoms, from Li through Fr, for high-precision measurements. An atom can encounter BBFF caused by the blackbody. We probed the roles of blackbody friction radiations of the stray electromagnetic fields present in the experimental set-up and another metallic shielding during measurements. Strengths of BBFFs on the alkali atoms were estimated by integrating complex parts of dynamic polarizabilities of atoms over a wide range of frequencies. Slowdown times of moving atoms due to these friction forces were analyzed as a function of temperature. The results were determined by both including and excluding nonresonant contributions in the polarizabilities of atomic states. This showed that the inclusion of nonresonant contributions affects the slowdown time of atoms significantly at low temperatures. Our study will be useful in accounting for these slowdown times in the ongoing and future high-precision experiments involving alkali atoms.

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This work was done in collaboration V. Badhan, S. Kaur, and B. Arora, of Department of Physics, Guru Nanak Dev University, Amritsar, Punjab 143005, India.

(B. K. Sahoo)

Determination of C_5 dispersion coefficients of the alkali atoms interacting with different material media

We determined the C_5 coefficients along with their uncertainties due to the quadrupole polarization effects of all the alkali atoms interacting with a metal (Au), a semiconductor (Si), and four dielectric materials (SiO_2, SiN_x, yttrium aluminum garnet, and sapphire). The required dynamic electric quadrupole (E2) polarizabilities were evaluated by calculating E2 matrix elements of a large number of transitions in the alkali atoms by employing a relativistic coupled-cluster method. A significant contribution towards the long-range van der Waals potential is made by the quadrupole polarization effects. Our finding showed that contributions from the C_5 coefficients to the atom-wall interaction potentials were pronounced at short distances (110 nm). The C_3 coefficients of a Fr atom interacting with the above material media were also reported. These results could be useful in understanding the interactions of alkali atoms trapped in different material bodies during high-precision measurements.

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This work was done in collaboration with H. Kaur, V. Badhan, and B. Arora of Department of Physics, Guru Nanak Dev University, Amritsar, Punjab 143005, India.

(B. K. Sahoo)

Relativistic normal coupled-cluster theory analysis of second- and third-order electric polarizabilities of Zn I.

We presented precise values of electric polarizabilities for the ground state of Zn due to second-order dipole and quadrupole interactions, and due to third-order dipole-quadrupole interactions. These quantities were evaluated in the linear response theory framework by employing a relativistic version of the normal coupled-cluster (NCC) method. The calculated dipole polarizability value was compared with available experimental and other theoretic- cal results, including those obtained using the ordinary coupled cluster (CC) methods in both nite-eld and expectation value evaluation approaches. We also gave a term-by-term comparison of contributions from our CC and NCC calculations in order to show differences in the results from these two methods. Moreover, we presented results from other lower-order methods to understand the role of electron correlation effects in the determination of the above quantities. A machine-learning-based scheme to generate optimized basis functions for atomic calculations was developed and applied here. From the analysis of the dipole polarizability result, the accuracy of the calculated quadrupole and third-order polarizability values was ascertained, for which no experimental values are currently available.

doi : https://doi.org/10.1103/PhysRevA.105.062815

(A. Chakraborty, S. K. Rithvik, and B. K. Sahoo)

Electric Dipole Moments and Static Dipole Polarizabilities of Alkali-Alkaline-Earth Molecules: Non-relativistic versus relativistic coupled-cluster theory analyses

We analyzed the electric dipole moments and static electric dipole polarizabilities of the alkali-metalalkaline-earth-metal (Alk-AlkE) dimers by employing nite-eld coupled-cluster methods in the frameworks of both nonrelativistic and four-component spin-free relativistic theories. In order to carry out comparative analyses rigorously, we considered those Alk-AlkE molecules made out of the lightest to the medium-heavy constituent atoms (Alk: Li to Rb and AlkE: Be through Sr. We presented the behavior of electron correlation effects as well as relativistic effects related to the size of the molecules. Uncertainties in the above quantities of the investigated Alk- AlkE molecules were inferred by analyzing our results from different forms of the Hamiltonian, basis set, and perturbative parameter for a few repre- sensitive molecules. We also provided empirical relations by connecting the average polarizabilities of the Alk-AlkE molecules with the polarizabilities of the corresponding Alk and AlkE atoms. We finally gave our recommended results and compared them with the literature values.

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This work was done in collaboration with V. S. Prasannaa of the Centre for Quantum Engineering, Research, and Education, TCG CREST, Salt Lake, Kolkata 700091, India

(R. Mitra and B. K. Sahoo)

Assessing the Precision of Quantum Simulation of Many-Body Eects in Atomic Systems using the Variational Quantum Eigensolver Algorithm

The emerging eld of quantum simulation of many-body systems is widely recognized as a very important application of quantum computing. A crucial step towards its realization in the context of many-electron systems requires a rigorous quantum mechanical treatment of the different interactions. In this pilot study, we investigated the physical effects beyond the mean-eld approximation, known as electron correlation, in the ground state energies of atomic systems using the classical-quantum hybrid variational quantum eigensolver algorithm. To this end, we considered three isoelectronic species, namely Be, Li^{-}, and B^{+}. This unique choice spans three classes neutral atom, an anion, and a cation. We have employed the unitary coupled-cluster ansatz to perform a rigorous analysis of two very important factors that could affect the precision of the simulations of electron correlation effects within a basis, namely mapping and backend simulator. We carried out our all- electron calculations with four such basis sets. The results obtained are compared with those calculated by using the full configuration interaction, traditional coupled-cluster, and unitary coupled-cluster methods, on a classical computer, to assess the precision of our results. A salient feature of the study involves a detailed analysis of the number of shots (the number of times a variational quantum eigensolver algorithm is repeated to build statistics required for calculations with IBM Qiskits QASM simulator backend, which mimics an ideal quantum computer. When more qubits be- come available, our study will serve as among the first steps taken towards computing other properties of interest to various applications such as new physics beyond the Standard Model of elementary particles and atomic clocks using the variational quantum eigensolver algorithm.

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This work was done in collaboration with Sumeet of the Institute for Theoretical Physics, FAU Erlangen-Nurnberg, 91058 Erlangen, Germany; Srinivasa V. Prasannaa of Centre for Quantum Engineering, Research and Education, TCG CREST, Salt Lake, Kolkata 700091, India; and B. P. Das of Department of Physics, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro-ku, Tokyo 152-8550, Japan

(B. K. Sahoo)

Polarization effects, shape resonances, and bound states in low energy positron elastic scattering by Zinc and Cadmium vapors

Low energy elastic positron scattering from Zn and Cd atoms was studied using model correlation potential. Special attention is given to the study of polarization effects through the incorporation of quadrupole polarizabilities and hyperpolarizabilities in the scattering potential. Resonant p-wave shape structures are found for both systems. Results showed that these become sharper and move to lower energies as the level of polarization of the potential is increased. Resonance was suppressed in Cd when the second hyperpolarizability was taken greater than 46000 a.u. and true p-wave bound states were formed. Comparison to previous calculations and dependence of the results with the scheme adopted to match the correlation and polarization components of the potential is discussed. We found that the elastic cross sections and the resonant effects do not depend on the specific form of the correlation potential but strongly depend on the polarization parameters and the matching point determined by the crossing between the correlation and polarization components of the potential. The value for the dipole-dipole quadrupole polarizability for Cd was specifically calculated using the relativistic coupled-cluster approach and was reported for the first time.

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This work was done in collaboration with F. Arretche, A. M. Andermann, and E. P. Seidel of the Physics Department, Universidade Federal de Santa Catarina, 88040-900, Florianopolis, Santa Catarina, Brazil and W. Tenfen of Physics Department, Universidade Federal de Pelotas, 96010-900, Pelotas, Rio Grande do Sul, Brazil

(B. K. Sahoo)

Precision measurement of the magnetic octupole moment in ^{45}Sc as a test for state-of-the-art atomic- and nuclear-structure theory

High-precision atomic calculations of the hyper one ends of the ground and first-excited states of ^{45}Sc were performed. These results were one order of magnitude more precise than the available literature. From the combined analysis of both atomic states, we inferred the nuclear magnetic octupole moment, including experimental and atomic structure-related uncertainties. With a single valence proton

outside of a magic calcium core, scandium is ideally suited to test a variety of nuclear models and to investigate in-depth the many intriguing nuclear structure phenomena observed within the neighboring isotopes of calcium. We performed nuclear shell-model calculations and furthermore explored the use of Density Functional Theory for evaluation. From this, mutually consistent theoretical values are obtrained, which are in agreement with the experimental value. This confirmed atomic structure calculations possess the accuracy and precision required for magnetic octupole moment measurements and showed that modern nuclear theory is capable of providing meaningful insight into this largely unexplored observable.

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This work was carried out in collaboration with R. P. Groote, J. Moreno, I. Moore and M. Reponen of the Department of Physics, University of Jyvskyl, PB 35(YFL) FIN-40351 Jyvskyl, Finland; J. Dobaczewski of Department of Physics, University of York, Heslington, York YO10 5DD, United Kingdom; A. Koszorus of the Department of Physics, University of Liverpool, Liverpool L69 7ZE, United Kingdom; and C. Yuan of Sino-French Institute of Nuclear Engineering and Technology, Sun Yat-Sen University, Zhuhai 519082, China.

(B. K. Sahoo)

A tolerance-enhanced spontaneous parametric downconversion source of bright entangled photons

Spontaneous parametric down-conversion (SPDC), a primary resource of photonic quantum entangled states, strongly depends on the intrinsic phase matching condition. This makes it susceptible to changes in factors such as the pump wavelength, crystal temperature, and crystal axes orientation. Such intolerance to changing environmental factors prohibits the deployment of SPDC-based sources in non-ideal environments outside controlled laboratories. Here, a novel system architecture based on a hybrid linear and non-linear the solution is shown to make the source tolerance enhanced without sacrificing brightness. This linear solution is a lens-axicon pair, judiciously placed, which is tested together with two common non-linear crystals, quasi-phase-matched periodically-poled KTiOPO4, and birefringent-phase-matched BiB3O6. This approach has the benefit of simultaneous tolerance to the environment and high brightness, which is demonstrated by using the proposed architecture as a stable entangled photon source and a spectral brightness as high as 22.58 $\pm$ 0.15 kHz mW^{-1} with a state fidelity of 0.95 $\pm$0.02, yet requiring a crystal temperature stability of only $\pm$0.8°C, a 5 enhanced tolerance as compared to the conventional high brightness SPDC configurations is reported. This solution offers a new approach to deployable high-brightness quantum sources that are robust to their environment, for instance, in satellite-based quantum applications.

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This work was done in collaboration with Andrew Forbes, University of the Witwatersrand, South Africa

(Sandeep Singh, Vimlesh Kumar, Anirban Ghosh, Andrew Forbes, G. K. Samanta)

Controlling the Coverage of Full Poincar Beams through Second-Harmonic Generatio

Ideal full Poincar (FP) beams contain all possible polarization states on the surface of the Poincar sphere and are readily created by linear optical techniques and, more recently, by nonlinear optical processes. An inherent limitation in the latter is the inability to achieve all polarization states, coined coverage, due to modal size, polarization, and modal weighting changes during the nonlinear conversion of the constituent modes. Here, we demonstrate a simple technique to control the coverage of FP beams, using second-harmonic generation as an example, from fully scalar (no coverage) to fully vectorial (full coverage). Our method for determining the coverage confirms the vectorial characteristics of the generated beams and reveals a balancing act between mode order, modal nonlinear efficiency, and initial relative modal weights, all in close agreement with that theoretically predicted. Our findings will hopefully be of value to the communities interested in nonlinear structured light, particularly for vectorial nonlinear modal creators and detectors and control of quantum hybrid entangled states.

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This work was done in collaboration with Andrew Forbes and his group, University of the Witwatersrand, South Africa.

(Subith Kumar, Ravi K. Saripalli, Anirban Ghosh, Wagner T. Buono, Andrew Forbes, and G. K. Samanta)

Theoretical Physics

Neutrino Propagation When Mass Eigenstates and Decay Eigenstates Mismatch

Possibility of probing physics beyond the Standard Model , which can show up at a sub-leading level in neutrino oscillation experiments , is an active area of research at present. One such scenario is the decay of neutrinos to invisible states. We consider propagation of the unstable neutrinos in matter governed by a non-Hermitian Hamiltonian. For this scenario, in general the oscillation and decay components of the effective Hamiltonian do not commute with each other and hence cannot be simultaneously diagonalised by unitary transformations. Thus the mass eigenstates and decay eigenstates may not be the same. We show that this mismatch is inevitable in matter. We develop a novel formalism for treating propagation of the invisibly decaying neutrinos in matter of uniform density and obtain compact analytic expressions for neutrino survival and conversion probabilities in two flavour formalism. The method employs a re-summation of the inverse Baker-Campbell-Hausdroff or Zassenhaus expansion. . The analytic results obtained match with the exact numerical results for constant density matter to a high precision and provide physical insights into possible effects of the decay of neutrinos propagating through Earth matter.

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This work was done in collaboration with D.S. Chattopadhyay, A. Dighe of Tata Institute of Fundamental Research , Mumbai and S. M. Lakshmi of National Centre for Nuclear Research Warsaw, Poland.

(Kaustav Chakraborty, Srubabati Goswami)

Lowering the scale of fermion triplet leptogenesis with two Higgs doublets

One of the major unresolved problems in physics is the origin of the observed baryon asymmetry of the Universe. The mechanism of leptogenesis, by which a lepton asymmetry is converted to a baryon asymmetry is widely discussed as a plausible mechanism for generating the baryon asymmetry. This can occur in the context of the seesaw models which can naturally give rise to small neutrino masses. We consider the possibility of generating the observed baryon asymmetry of the Universe via leptogenesis in the context of a triplet fermion-mediated type-III seesaw model of neutrino mass. With a hierarchical spectrum of the additional fermions, the lower bound on the lightest triplet mass is 10^{10} GeV for successful leptogenesis. Lowering the scale of leptogenesis is motivated from the view point of testability and naturalness. We investigate the possibility of lowering this bound in the framework of two-Higgs-doublet models. We find that the bounds can be lowered down to 10^7 GeV for a hierarchical spectrum. If we include the flavor effects, then a further lowering by one order of magnitude is possible. We also discuss if such lowering can be compatible with the naturalness bounds on the triplet mass.

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This work was done in collaboration with Drona Vatsayana of University of Valencia, Spain.

(Srubabati Goswami)

Leptogenesis with eV scale sterile neutrino

We consider the minimal extended seesaw model that can accommodate an eV scale sterile neutrino. The scenario also includes three heavy right-handed neutrinos in addition to the light-sterile neutrino. In this model, the active-sterile mixing acts as nonunitary parameters. If the values of these mixing angles are large, the model introduces deviation of the Pontecorvo-Maki-Nakagawa-Sakata matrix from unitarity to this order. We find that the oscillation data from various experiments impose an upper bound on the lightest heavy neutrino mass scale as 10^{11} GeV in the context of this model. We study vanilla leptogenesis in this scheme, where the decay of the heavy right-handed neutrinos in the early Universe can give rise to the observed baryon asymmetry. Here, even though the eV scale sterile neutrino does not participate directly in leptogenesis, its effect is manifested through the nonunitary effects. We find that the parameter space that can give rise to successful leptogenesis is constrained by the bounds on the active-sterile mixing as obtained from the global analysis.

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This work was done in collaboration with K.N. Vishnudath of Indian institute of Mathematical Sciences, Chennai, A. Mukherjee of University of Kolkata , Kolkata

(Srubabati Goswami, N. Narendra)

Analytic treatment of 3-flavor neutrino oscillation and decay in matter

We present compact analytic expressions for 3-flavor neutrino oscillation probabilities with invisible neutrino decay, where matter effects have been explicitly included. We take into account the possibility that the oscillation and decay components of the effective Hamiltonian do not commute. This is achieved by employing the techniques of inverse Baker-Campbell-Hausdorff (BCH) expansion

and the Cayley-Hamilton theorem applied in the 3-flavor framework. If only the vacuum mass eigenstate ν_3 decays, we show that the treatment of neutrino propagation may be reduced to an effective 2-flavor analysis in the One Mass Scale Dominance (OMSD) approximation. The oscillation probabilities for $\mathrm{P}_{\mu\mu}$, P_{ee}, $\mathrm{P}_{e\mu}$ and $\mathrm{P}_{\mu e}$ — relevant for reactor, long baseline and atmospheric neutrino experiments — are obtained as perturbative expansions for the case of only ν_3 decay, as well as for the more general scenario where all components of the decay matrix are non-zero. The analytic results thus obtained match the exact numerical results for constant density matter to a high precision and provide physical insights into possible effects of the decay of neutrinos as they propagate through Earth matter. We find that the effects of neutrino decay are most likely to be observable in $\mathrm{P}_{\mu\mu}$. We also point out that at any long baseline, the oscillation dips in $\mathrm{P}_{\mu\mu}$ can show higher survival probabilities in the case with decay than without decay, and explain this feature using our analytic approximations.

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This work was done in collaboration with D.S. Chattopadhyay, A. Dighe of Tata Institute of Fundamental Research

(Kaustav Chakraborty, Srubabati Goswami)

Energizing gamma ray bursts via Z' mediated neutrino heating

The pair annihilation of neutrinos to electron-positron pairs can energize violent stellar explosions such as gamma ray bursts (GRBs). The energy in this neutrino heating mechanism can be further enhanced by modifying the background spacetime over that of Newtonian spacetime. However, one cannot attain the maximum GRB energy (10^{52} erg) in either the Newtonian background or Schwarzschild and HartleThorne background. On the other hand, using modified gravity theories or the Quintessence field as background geometries, the maximum GRB energy can be reached. In this paper, we consider extending the standard model by an extra $\mathrm{U}(1)_{\mathrm{B-L}}$ gauge group and augmenting the energy deposition by neutrino pair annihilation process including contributions mediated by the Z' gauge boson belonging to this model. From the observed energy of GRB, we obtain constraints on $\mathrm{U}(1)_{\mathrm{B-L}}$ gauge coupling in different background spacetimes. We find that the bounds on gauge coupling in modified gravity theories and quintessence background are stronger than those coming from the neutrino-electron scattering experiments in the limit of small gauge boson masses. Future GRB observations with better accuracy can further strengthen these bounds.

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This work was done in collaboration with Dr. T.K Poddar of, Tata Institute of Fundamental Research, Mumbai and Dr. Arvind Kumar Mishra ofIndian Institute of Science Education and Research, Pune.

(Srubabati Goswami)

Light Cone Sum Rules and Form Factors for $p \to e^+\gamma$

Observation of proton decay would unambiguosly point towards physics beyond the Standard Model of particle physics. Usually considered mode of decay of proton is the pionic mode. However, in several extensions of the standard model, there could be other modes that are dominant like decays to second generation of quarks and leptons. In addition, the two body radiative mode $p \to e^+\gamma$ is also an interesting one since it is free from nuclear absorption effects. This helps in alleviating part of the suppression due to fine structure constant. The mode is studied in detail and the relevant non-perturbative form factors are computed employing two different inputs: proton distribution amplitudes and photon distribution amplitudes. The form factors for both the cases are provided, with the associated errors. These can be used for phenomenological studies.

doi : https://doi.org/10.1007/JHEP06(2022)161

(Anshika Bansal, Namit Mahajan)

Top-philic dark matter in a hybrid axion framework

Diverse Astro-cosmo experiments established undeniable evidence of the existence of yet unknown matter all around our Universe, which significantly dominates over our known fundamental matter particles. Hence theoretical and experimental searches for such dark matter particles are very active research domain. PRL groups are also pursuing such studies actively. The present work explores a two-component dark matter scenario in an extended version of the axion framework. Axion is a hypothetical particle proposed to solve the strong CP problem in quantum chromodynamics (QCD). It is also a candidate for dark matter. This work focuses on how the vector-like quark in this extension affects dark matter and collider phenomenology. This coloured particle can change the allowed dark matter parameter space by opening new co-annihilation and direct detection channels. Additionally, it creates a unique topology for generating a boosted-top pair with considerable missing transverse momentum at the Large Hadron Collider (LHC), which can test and exclude a vast region of parameter space. The LHC experiment accelerates and collides proton beams at very high energy to study the properties of subatomic particles and the fundamental forces of nature.

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This work was done in collaboration with Rishav Roshan, Kyungpook National University, Republic of Korea.

(Anupam Ghosh, Partha Konar)

Freeze-in dark matter through a tangibly forbidden channel

A plethora of celestial experiments confirmed that our known fundamental matter particles only constitute a small part of the Universe. Instead, it is dominated by some mysterious, unknown matter known as dark matter. Hence, theoretical modeling and experimental findings for such dark matter candidates are active research domains in which PRL groups also participate. Several competing theories exist on how these dark matter particles were produced in the early phase when the Universe was hot and dense. Moreover, how dark matter (relic) density froze in terms of the

expansion of the Universe and interaction with other particles. The present work explores the possibility of gradual dark matter production from decay through a freeze-in mechanism, where feeble interaction with the Standard Model bath can easily evade the severe constraints of the direct search experiments. This scenario becomes even more interesting if one includes the thermal masses of the particles involved in dark matter phenomenology. Incorporating such thermal corrections opens the possibility of dark matter production via channels that remain kinematically disallowed in the standard setup. We investigate in a minimally extended new physics framework, also known to resolve the muon (g - 2) anomaly.

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This work was done in collaboration with Nabarun Chakrabarty, IIT Kanpur and Rishav Roshan, Kyungpook National University, Republic of Korea.

(Partha Konar, Sudipta Show)

The case of itinerant magnetism in $CaMn_2Al_{10}$: self-consistent renormalisation (SCR) theory study

We have applied the powerful self-consistent renormalization theory of spin fluctuations for the system $CaMn_2Al_{10}$ discovered in 2015 and was conjectured to be an itinerant magnet. We have calculated the inverse static i.e. (paramagnetic) susceptibility and have compared it with the experimental data (Steinke et al 2015 Phys. Rev. B 92 020413). The agreement is very good. We have calculated spin fluctuations at various temperatures and have also estimated the strength of the electronic correlation i.e. (U=0.3136 eV) in the Hubbard Hamiltonian. Based on our quantitative explanation of the inverse static i.e. (paramagnetic) susceptibility data within the framework of self-consistent renormalization theory, we can decisively conclude $CaMn_2Al_{10}$ exhibits the phenomena of itinerant magnetism. Further, our density functional theory (DFT) and DFT+U calculations corroborate the strong Mn-Al hybridization which is the key to the itinerant magnetism in this system. Our estimated correlations strength will provide a foundation for further studies of itinerant magnetism in this system.

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(Bharathiganesh Devanarayanan, Akariti Sharma, Pratik D Patel, and Navinder Singh)

Tunable phase transitions in half-Heusler TbPtBi compound

We report various phase transitions in half-Heusler TbPtBi compound using density functional theory. Specifically, the inclusion of spin-orbit coupling (SOC) leads to the band inversion resulting in the transition from the metallic to the topological semimetallic phase. However, in the presence of SOC, there is a phase transition from the topological semimetal to the trivial semimetal when the material is subjected to compressive strain (-7%). Subsequently, under the further increase of compressive strain $(\geqslant -7\%)$, we find an opening of a direct band gap at the point, driving the system from the trivial semimetallic to a semiconducting state with changes in the sequence of the bands. In the absence of SOC, only the transition from the metallic to the semiconducting phase is noticed. Under tensile strain, the TbPtBi compound maintains its phase as in the unstrained condition but with an increase in the hole pocket at the Fermi level, both in the absence and presence of SOC. These tunable phase transitions (especially as a fraction of strain) make this compound very promising for applications in various quantum devices, such as highly sensitive strain gauges.

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(Pratik D Patel, Akariti Sharma, Bharathiganesh Devanarayanan, Paramita Dutta, and Navinder Singh)

Anatomy of scalar mediated proton decays in SO(10) models

Realistic models based on the renormalizable Grand Unified Theories (GUT) have varieties of scalars, many of which are capable of mediating baryon (B) and lepton (L) number non-conserving processes. We identify all such scalar fields residing in 10, $\overline{126}$ and 120 dimensional irreducible representations of SO(10) which can induce baryon and lepton number violating interactions through the leading order $d = 6$ and $d = 7$ operators. Explicitly computing their couplings with the Standard Model fermions, we derive the effective operators including the possibility of mixing between the scalars stemming from a given representation. We find that such interactions at $d = 6$ are mediated by only three sets of scalars: $\mathrm{T}(3, 1, -1/3)$, $\mathscr{T}(3, 1, -4/3)$ and $\mathbb{T}(3, 3, -1/3)$ and their conjugates. In the models with 10 and $\overline{126}$, only the first has appropriate couplings to mediate the proton decay. While $\mathscr{T}$ and $\mathbb{T}$ can induce baryon number violating interactions when 120 is present, $\mathscr{T}$ does not contribute to the proton decay at tree level because of its flavour antisymmetric coupling. We give general expressions for partial widths of proton in terms of the fundamental Yukawa couplings and use these results to explicitly compute the proton lifetime and branching ratios for the minimal nonsupersymmetric SO(10) model based on 10 and $\overline{126}$ Higgs. We find that the proton preferably decays into $\overline{\nu}\mathrm{K}^+$ or $\mu^+\mathrm{K}^0$ and list several distinct features of scalar mediated proton decay. If the latter dominates over the gauge mediated contributions, the proton decay spectrum provides a direct probe to the flavour structure of the underlying GUT.

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(Ketan M. Patel, Saurabh K. Shukla)

Radiatively generated fermion mass hierarchy from flavor nonuniversal gauge symmetries

A framework based on a class of Abelian gauge symmetries is proposed in which the masses of only the third generation quarks and leptons arise at the tree level. The fermions of the first and second families receive their masses through radiative corrections induced by the new gauge bosons in the loops. It is shown that the class of

Abelian symmetries which can viably implement this mechanism are flavor nonuniversal in nature. Taking the all-fermion generalization of the well-known leptonic $L_\mu - L_\tau$ and $L_e - L_\mu$ symmetries, we construct an explicit renormalizable model based on two U(1) which is shown to reproduce the observed fermion mass spectrum of the Standard Model. The first and second generation fermion masses are loop suppressed while the hierarchy between these two generations results from a gap between the masses of two vector bosons of the extended gauge symmetries. Several phenomenological aspects of the flavorful new physics are discussed and lower limits on the masses of the vector bosons are derived.

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(Gurucharan Mohanta, Ketan M. Patel)

Spectrum of color sextet scalars in realistic SO(10) GUT

Incorporation of the standard model Yukawa interactions in a Grand Unified Theory (GUT) often predicts varieties of new scalars that couple to the fermions and lead to some novel observational effects. We assess such a possibility for the colour sextet diquark scalars within the realistic renormalizable models based on $SO(10)$ GUT. The spectrum consists of five sextets: $\Sigma \sim (6,1,-\frac{2}{3})$, $S \sim (6,1,\frac{1}{3})$, $\overline{S} \sim (\overline{6},1,-\frac{1}{3})$, $\mathscr{S} \sim (6,1,\frac{4}{3})$ and $\mathbb{S} \sim (\overline{6},3,-\frac{1}{3})$. Computing explicitly their couplings with the quarks, we evaluate their contributions to the neutral meson-antimeson mixing and baryon number-violating processes like neutron-antineutron oscillation. The latter arises because of a $B-L$ violating trilinear coupling between the sextets which also contributes to some of the quartic couplings and perturbativity of the same leads to strong limits on the sextet masses. Using the values of the $B-L$ breaking scale and Yukawa couplings permitted in the realistic models, we derive constraints on the masses of these scalars. It is found that Σ along with any of the remaining sextets cannot be lighter than the $B-L$ breaking scale, simultaneously. In the realm of realistic models, this implies no observable n-$\bar{n}$ oscillation in near future experiments. We also point out a possibility in which sub-GUT scale Σ and a pair of S, allowed by the other constraints, can viably produce the observed baryon asymmetry of the universe.

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(Ketan M. Patel, Saurabh K. Shukla)

Transport signatures of a topological superconductor junction

We have studied a finite-size topological Josephson junction formed at one-dimensional helical edges of a two-dimensional topological insulator to investigate the impact of Cooper pair symmetries on electron transport. Due to the finite size junction electron transport is highly tunable by the superconducting phase difference across the junction. We have observed that odd-frequency Cooper pairs become the only type of pairing to survive inside the topological junction. Odd-frequency pairing was never considered in Bardeen-Cooper-Schrieffer (BCS) theory and later proved necessary because of its unavoidable contribution to transport phenomena. Separation and detection of odd-frequency Cooper pairs in superconductors or superconducting junctions are always challenging. Our work offers a highly tunable detection scheme for odd-frequency Cooper pairs. Our results support the potential of the topological Josephson junction for application purposes.

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This work was done in collaboration with researchers from Autonomous University of Madrid, Spain, and Uppsala University, Sweden.

(Paramita Dutta)

Precise probing of the inert Higgs-doublet model at the LHC

The inert Higgs-doublet model provides a simple framework to accommodate a viable Higgs portal scalar dark matter candidate, together with other heavier scalars of mass 100 GeV or more. We study the effect of next-to-leading order (NLO) QCD corrections in this scenario in the context of the Large Hadron Collider. $\mathcal{O}(\alpha_s)$ corrections to the gluon-gluon-Higgs effective coupling have been taken into account in this study wherever appropriate. We find such corrections have a significant impact on various kinematic distributions and reduce scale uncertainties substantially. Fixed order NLO results are matched to the Pythia8 parton shower (PS) and the di-fatjet signal associated with the missing transverse momentum is analyzed, as this channel has the ability to explore its entire parameter space during the next phase of the LHC run. A closer look at the NLO+PS computation indicates a sizeable NLO effect together with a subdued contribution from associated production of the heavy scalar compared to the pair production, thereby leading to a refined analysis strategy during the multivariate analysis of this signal.

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(Anupam Ghosh Partha Konar, Satyajit Seth)

Non-local slicing approaches for NNLO QCD in MCFM

We present the implementation of several processes at next-to-next-to leading order (NNLO) accuracy in QCD in the parton-level Monte Carlo program MCFM. The processes treated are $pp \to H, W^{\pm}, Z, W^{\pm}H, ZH, W^{\pm}\gamma, Z\gamma$ and $\gamma\gamma$ and, for the first time in the code, $W^+W^-, W^{\pm}Z$ and ZZ. Decays of the unstable bosons are fully included, resulting in a flexible fully differential Monte Carlo code. The NNLO corrections have been calculated using two non-local slicing approaches, isolating the doubly unresolved region by cutting on the zero-jettiness, τ_0, or on q_T , the transverse momentum of the colour singlet final-state particles. We find that for most, but not all processes the q_T slicing method leads to smaller power corrections for equal computational burden.

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(Satyajit Seth)

Statistical Nuclear Spectroscopy with q-normal and bivariate q-normal distributions and q-Hermite polynomials

Statistical nuclear spectroscopy (also called spectral distribution method), introduced by J.B. French in late 60's and developed in detail in the later years by his group and many other groups, is based on the Gaussian forms for the state (eigenvalue) and transition strength densities in shell model spaces with their extension to partial densities defined over shell model subspaces. The Gaussian forms have their basis in embedded random matrix ensembles with nuclear Hamiltonians consisting of a mean-field one-body part and a residual two-body part. However, following the recent random matrix results for the so called Sachdev-Ye-Kitaev model due to Verbaaarschot et al, embedded random matrix ensembles with k-body interactions are re-examined and it is shown that the density of states, transition strength densities and strength functions (partial densities) in fact follow more closely the q-normal (univariate or bivariate as appropriate) distribution. The parameter q is related to the fourth moment of these distributions with $q = 1$ giving Gaussian and $q = 0$ giving semi-circle form. The q-normal has the important property that it is bounded for $0 \leq q < 1$. Following these, we have developed statistical nuclear spectroscopy based on q-normal (univariate and bivariate) distributions and the associated q-Hermite polynomials. In particular, formulation is given in detail for nuclear level densities, shell model orbit occupancies, transition strengths (for electromagnetic and β and double β-decay type operators) and strength sums.

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Various Events, and Outreach Activities at PRL

Flagging off Aditya L1 Payload

On November 23rd, 2022, the PRL Council Chairman visited the Physical Research Laboratory and had the honour of flagging off the STEPS payload for ADITYA L1 mission. This visit was a significant milestone for the PRL team, as they were able to showcase their progress and receive valuable feedback from the Council Chairman. The ADITYA L1 mission aims to study the sun's corona and its influence on the Earth's upper atmosphere. The mission will be launched on-board a satellite, which will be placed in a unique halo orbit around the Lagrangian point L1, where the gravitational pull of the sun and the Earth balance each other. This will enable the satellite to continuously observe the sun without any interruption from the Earth's shadow. The ADITYA L1 mission is the first of its kind and will provide new insights into the various processes that occur in the sun's corona, such as the acceleration of solar winds and the origin of solar flares. This information will help scientists understand how the sun affects the Earth's upper atmosphere, including the ionosphere and the thermosphere.

Solar-wind Ion Spectrometer (SWIS) Flag Off

The Physical Research Laboratory (PRL) witnessed an exciting event on December 19, 2023, in the form of SWIS payload flag-off to URSC, Bangalore in the presence of around 150 people, including scientists and engineers from PRL and SAC, as well as some distinguished invitees. The flag-off ceremony was held at the PRL Thaltej Campus and was led by Prof. Anil Bhardwaj, who officially flagged-off SWIS sub-system of ASPEX payload. During the event, posters were displayed that provided details on the ADITYA-L1 mission and ASPEX payload, and a video was shown that showcased different stages of development for the SWIS (and STEPS) subsystem of ASPEX payload. Note, STEPS subsystem of the ASPEX payload was flagged-off earlier. The flag-off of the SWIS, was a historic moment for PRL and a testament to the dedication and hard work of the scientists and engineers involved for the past many years. The event was a celebration of the mission's progress and an exciting start to the next phase of the journey. We will be eagerly looking forward to the data that ASPEX will send from the orbit.

PRL Student Chapter

PRL student chapter was formed on 15 June 2015. Currently, the chapter has more than 40 PhD student members from different divisions of PRL. Although the PRL student chapter started with the vision of popularizing optics and photonics among school and college students through hands-on experiments, the chapter has expanded its scientific portfolio by incorporating hands-on experiments from other branches of science. So far, the PRL student chapter has devised more than 50 hands-on basic experiments to explain many phenomena in our daily lives. PRL student chapter has been organizing its annual student conference since 2016. In 2022, the PRL student chapter organized its seventh edition of the yearly conference in offline mode.

National Space Science Exhibition 2022

The NSSE 2022 was conducted in the city of Kolkata from 6th 11th December 2022 as a part of the 21st National Space Science Symposium (NSSS2022). Locally co-ordinated by IISER Kolkata, the venue was very aptly chosen to be as the Science City of Kolkata. Daily hundreds of people ranging from School Students, Science Enthusiasts, Elderly people and other general public attend the Science City, and the Event was open to all with a valid Science City Pass. This event was well advertised all across the city and the state, and had thousands of people coming in, especially for the exhibition. The Exhibition had several interesting features such as:

- Space Science Exhibits from eminent institutions all over the country,
- Popular Science Lectures organised in the city of Kolkata
- Several Outreach Booths
- Many seminars organised in local language for Interaction with space Scientists
- A special panel discussion with the Women in Science
- A panel talk for interaction between Industry and Academia

PRL also participated in the exhibition and sent a team of scientists to the event for outreach purpose. We had a stall in the event, in which several posters were put up, covering all the scientific domains of research in PRL. We also had Audio-Visual presentations to be displayed at our stall. The team of PRL spent hours discussing about science and motivating young minds and explaining the importance of fundamental research to adults who visited the exhibition.

PRL team made special arrangements for young kids, who were too young to understand the intricacies related to scientific studies, but have an infinite power of imagination. These children were engaged by the means of paintings, and by the end of the program, we had over 100 paintings collected with us. All of these depicted the hidden fire and curiosity within the minds.

Overall, it was a very successful science outreach event, which will directly and indirectly impact hundreds of children to take up science as a career option in future; or at least, develop a scientific perspective in life, which will be an asset to have. The team of PRL scientists also had a great time interacting with all the attendees. It truly felt like an achievement, taking our work out to the general public and creating scientists of the future.

Science Carnival

Rishitosh K. Sinha: Attended and represented PRL in the Science Carnival organized by Gujarat Science City from 28th February to 4^{th} March 2023. Five-day Science Carnival 2023, organized at Science City, Ahmedabad from 28 Feb - 4 Mar, 2023. Harish Gadhavi: PRL participated in Science Exhibition at Science Carnival 2023 from 28 Feb-4 Mar, 2023 held at Gujarat Science City, Ahmedabad. SPA-SC Division showcased the Aditya-L1Payload at this exhibition.

Science Express

Science Express: Indore during January 26-29, 2023. Science Express: Pune during February 13-17, 2023. Science Express event of PRL in four states, Rajasthan, Gujarat, Madhya Pradesh, and Maharashtra demonstrating live science experiments to 15000 students.

National Science Day 2023

The Physical Research Laboratory recently celebrated National Science Day (NSD) 2023 in two phases, with a variety of events and activities taking place. In Phase 1, PRL members visited 19 different centres across Gujarat and conducted a screening test for the Aruna Lal Scholarship on 22 January 2022. This year, two new centres were added, and the test covered 163 schools in the state, with 868 students appearing. Encouragingly, 44% of these students were girls. Along with the screening exam, the PRL team demonstrated science experiments at 11 centres, with 22 experiments being covered through live feeds from other centres, and 5000 students visited the science express. In addition, the Vikram Sarabhai Protsahan Yojana (VIKAS) Scholarship exam was also conducted at 19 centres in Gujarat.

In Phase 2, the students shortlisted from the screening exam were invited to visit PRL and participated in various competitions on Saturday, 25 February 2023. Over 150 students and 60 teachers / accompanying parents visited PRL on this day. Some of the selected students were interviewed for the Aruna Lal scholarship. The significant activities arranged for students and teachers were;

1. a posters and models competition,
2. an on-the-spot quiz competition in digital format,
3. a talk on 'Introduction to science at PRL',
4. a talk on 'Cyber Safe Behavior - See Yourself in Cyber',
5. interaction with PRL scientists,
6. science experiments demonstrations,
7. visits to the workshop and library,
8. live observation of the featureful Sun through a telescope,
9. a science cartoon competition,
10. a virtual tour to Mt Abu Observatory and Udaipur Solar Observatory.

To mark the platinum jubilee celebrations, 75 prizes were awarded, including 5 Aruna Lal Scholarships for 2023. The students, teachers, and accompanying parents enjoyed the activities and actively participated, making for a successful and enjoyable celebration of National Science Day.

Vigilance Awareness week 2022

Based on the Circular dated 08.09.2022 of Central Vigilance Commission (CVC) and endorsement dated 13.09.2022 of DOS thereon, the Vigilance Awareness Week (VAW)2022 was observed in PRL from 31st October 2022 to 6th November 2022. The theme of the VAW-2022 was " - "/"Corruption free India for a developed nation". All the staff Members of PRL took Integrity Pledge at their respective work places on 31.10.2022. Few of the Photographs of PRL staffs taking Integrity Pledge are pasted below. Apart from Integrity Pledge, all staff members were encouraged to take Integrity E-pledge in CVC portal (https://pledge.cvc.nic.in). A total of 51 PRL Staff have taken E-pledge for which online Certificates are downloadable from CVC portal. Integrity E-Pledge as an organisation has also been taken for PRL and the certificate so received is pasted below:

An online quiz on the occasion of VAW-2022 was also conducted on 04.11.2022 in which 21 PRLites had participated. The winners of this quiz were felicitated with a certificate and cash prize during the Republic Day celebration on 26.01.2023.

An online awareness lecture on this year theme " - "/"Corruption free India for a developed nation" was planned to be conducted during the awareness week of 31.10.2022 to 04.11.2022. However, due to non-availability of speakers during the above period, the same could not be conducted as planned.

Celebration of Ambedkar Jayanti

The celebration of Dr. B. R. Ambedkar Jayanti was organized at all campuses of PRL on 9th June 2022 (Thursday). As mandated by the Department of Space/GoI, a special lecture was arranged at K R Ramanathan Auditorium. Dr. Bodhiraj Vishwas, an eminent scholar and social worker spreading Ambedkar's work and message, was invited to give this address on the occasion of the celebration of Ambedkar Jayanti. Dr. Vishwas did his PhD in Buddhism and is known for his works and deep knowledge of this philosophy. He has been working as a state president of Gujarat, The Buddhist Society of India, since 2018. He is also working as an income tax officer at Ahmedabad.

The function started by first playing the National Anthem, followed by the lighting of the lamp before Ambedkar's picture and paying flower homage to Baba Saheb. Dr. Anil Bhardwaj, Director, PRL, other dignitaries, and guests joined in lighting the lamp. After that, the programme started with the Director welcoming the chief guest by presenting him with a bamboo plant. Dr. Konar, Chairman of the organizing committee, introduced the speaker and invited him to the dais to deliver the lecture.

Dr. Viswas gave an excellent lecture on "Why Dr. B. R. Ambedkar chose Buddhism as a Social Movement". He emphasized India's culture of nonviolence, Baba Saheb's journey, his learning through debate and a scientific approach to problem-solving. He further discussed how Ambedkar translated those to build the foundation of modern India. The event was live telecast through online Mode for the PRL members at Mt. Abu.

After completion of the speech, the Director invited the speaker and other dignitaries for tree plantation at PRL.

Complimentary lunch arrangements were made at all four PRL campuses, which includes the Thaltej campus, Udaipur Solar Observatory and Mt. Abu infrared observatory, to celebrate the occasion. Along with PRL staff and students, all including contractual staff, daily-wagers and visitors present on this day were invited for lunch.

The Cosmic Origin talk series

"The Cosmic Origin talk series", a weekly talk series in Physical Research Laboratory (online mode) aims to foster mutual collaboration and discussion between astronomy, astrophysics, astrochemistry, and planetary scientists in India and aboard.

Celebration of World Environment Day

The Department of Space (DOS) has conveyed the instructions issued by the Ministry of Environment, Forest and Climate Change to spread the message of challenges of climate change and pollution as well as the concerns of nature and biodiversity loss. This activity was earmarked to be undertaken on the World Environment Day on June 5, 2022.

The PRL Committee for Azadi ka Amrit Mahotsav (C-AKAM), has undertaken up this activity to celebrate the world environment day at PRL. An event was organised at PRL K Ramanathan Auditorium on 9th June 2022. The event aimed at discussing the #savethesoil movement and spreading the message of #OnlyOneEarth theme. The theme highlights the fact that safeguarding the planets finite natural resources of critical importance. An in-house documentary portraying the research activities that are carried out in PRL which are imperative in tackling the different ecological problems, was displayed/screened in K.R. Ramanathan Auditorium. Scientists from varying fields of research including hydrology, atmospheric sciences, aerosol chemistry, geochemistry talked about the importance of their respective research and how they contribute directly or indirectly to addressing the environmental problems, climate change, air quality, soil degradation etc. The documentary also depicted and showcased the biodiversity of the PRL campuses, the annual tree plantation events and the management of biodegradable waste using a BioCompost unit that has been installed in the campus. Several members of PRL also pledged to save the environment in conjunction with the theme of #OnlyOneEarth theme. About 100 participants attended the programme. This followed by a presentation by Ms. Shivanshi Gupta, Scientist/Engineer-SC, PRL on the topic Soil Extinction: An Existential Threat. The presentation introduced the audience to the serious issue of soil degradation, informed them on how, if not addressed at the earliest, it can result in a massive, global food crisis in future, and made them aware on how this problem is directly related to many other problems faced by humanity today viz nutritional deficiency, water scarcity, floods, droughts, climate change, farmer suicide, migration, etc. It concluded with an appeal to the audience to come together and raise their voice to save our soil. The presentation was very lucid and informative and conveyed a potential societal awareness message. This followed by tree plantation by the Director, PRL, Dean, PRL, Chair, PPEG, Chair, C-AKAM, Invited Guests and Senior Faculty Members of PRL. Mr. Sanjay Wairagade, convener, world environment day celebration committee, was actively involved with C-AKAM team in successful organisation of this event.

Celebration of International Day of Yoga

The 8th International Day of Yoga (IDY-2022) was celebrated on 21 June 2022 (Tuesday) at PRL. The event was organized by the Committee Azadi Ka Amrut Mahotsav (AKAM). The Yoga Day programme was organized at PRL Library Lawn. The programme started with an overview of International Day of Yoga by Shri. Pradeep Kumar Sharma, Convener, C-AKAM. A brief introduction of the Yoga instructors, Mr. Gyan Acharya, Founder & CEO of Gyanish Yoga Foundation, Ms. Priti Iyengar, Registered Yoga Teacher and Mr. V Ranganathan, Yoga Practitioners for 35 years was given by the Dr. Lokesh Kumar Sahu, Chair, Azadi Ka Amrut Mahotsav Committee. Before the demonstration, Mr. Gyan Acharya explained the meaning of Yog, its history from the ancient times and its importance in our life. Thereafter, the practice session was conducted by Mr. Gyan Acharya by delivering the instructions on doing various types of Asanas and explaining the benefit of each pose in the Asanas. Ms. Priti Iyengar gave stepwise practical demo of each Asanas. Mr. V Ranganathan observed each participant and updated them on making the correct postures.

D. Anil Bhardwaj, Director, PRL welcomed the Yoga instructors by presenting them a Tulsi plant pots. Ms. Ishita Shah has conveyed Vote of Thanks. At the end of the Yoga session, a Surya-Namaskar Competition under AKAM was organized. The competition was categorized into three groups. i.e. Below 16 years, 16 to 29 years and 30 & above. In the said competition, total 3 sets Surya-Namaskar is to be done by the participants in 4 minutes with making the correct poses of Surya-Namaskar in each step. Total 30 number of participants have participated in the said Competition. The winners of the Surya-Namaskar Competition were awarded with Trophies.

Digital India Week

As per the directives of GoI, Digital India Week was celebrated at PRL from 04.07.2022 to 10.07.2022. To make PRL users aware about overall functioning of IT services and how our user can use available services like Nextcloud, VPN, Element alongwith cyber safety & security, an online interactive session was scheduled on 07.07.2022 through Bluejeans. Many PRL members participated in the above session.

Har Ghar Tiranga

"Har Ghar Tiranga is an initiative to invoke a sense of ownership in the people and to celebrate Azadi ka Amrit Mahotsav in the spirit of Jan Bhagidari.Har Ghar Tiranga is a campaign under the aegis of Azadi Ka Amrit Mahotsav to encourage people to bring the Tiranga to home and to hoist it to mark the 75th year of Indias independence. Bringing the flag home collectively as a nation in the 75th year of independence thus becomes symbolic of not only an act of personal connection but also an embodiment of the commitment to nation building. The idea behind the initiative is to invoke the feeling of patriotism in the hearts of the people and to promote awareness about the Indian National Flag.

In adherence to Home Home Secretary, GoI D.O. letter No. 2/01/2020-Public(Part-III) dated 20.07.2022 and vide DOS Endorsement No. A.27012/8/2021-V dated 28.07.2022 and an appeal dated 27.07.2022 from Secretary, DOS/ Chairman, ISRO for "Implementing Har Ghar Tiranga Programme, this event was organized at PRL. It was a part of Azadi Ka Amrit Mahotsav. Being the 76th year of India's independence and 75th anniversary of the establishment of Physical Research Institute (PRL), to mark this

as a memorable campaign, a small programme was organized to kickstart the campaign. Around 750 National flags and wooden sticks were distributed to the Staffs, research scholars, trainees, contractual workers etc. Dr. Anil Bhardwaj, Director, PRL distributed the National Flags to PRL members. To boost the patriotism among the PRL members, a walkathon was also led by the Director and Dean PRL through the main campus. The group photos were taken.

Further, a Notification was also circulated through which PRL members were requested to pin the National Flag at their premises and were sensitized about the “Har Ghar Tiranga campaign. The Handout, duly mentioning the “dos and donts with respect to hoisting National Flag was too circulated. PRL Members were encouraged to click and upload selfies with Tiranga on www.harghartiranga.com and to download certificate.

Inter-Area/Division Tug of War Competition

Tug of war is a sport that pits two teams against each other in a test of strength: teams pull on opposite ends of a rope, with the goal being to bring the rope a certain distance in one direction against the force of the opposing team’s pull.

On Vikram Jayanti Celebration at PRL on 12th August, 2022 (Friday), an Inter-Division/Area Tug Of War Competition was organized at PRL Library Lawn under the Azadi Ka Amrit Mahotsav Celebrations. Area/ Division wise Teams of 8 members were formed. The teams were informed about the rules of the game. Dr. Anil Bhardwaj, Director, PRL met each player and encouraged them to give their best in the game.

The event was conducted on a knockout basis. The game was refereed by Dr. Ravi Bhushan and Mr. P K Sivadasan. Each team put their best efforts to win the game. The audience cheered each team and boosted their energy. At the end of the Final round, Team Services won the first prize, followed by Team GSDN. Team Administration won the third prize.

Further, four teams, Team Ahilya, Team Usha, Team Teresa, and Team Lakshmi were formed of Female staff members. These teams participated with commendable strength and enthusiasm. The atmosphere was charged with zeal and fervour with the first round itself. At the end of Four matches, Team Ahilya stood first in the game whereas Team Usha was runner-up. Team Teresa and Team Lakshmi both were ranked in the third position.

All the PRL Members enjoyed the event thoroughly. It was a Spectacular event.

Independence Day celebration at PRL

The 76th Independence Day was celebrated at PRL on 15th August 2022 (Monday) under the Azadi Ka Amrit Mahotsav.

The day started by hoisting the National flag by Dr. Anil Bhardwaj, Director, PRL which was followed by the National Anthem. As per protocol, a Parade was done by CISF, PRL which signifies methodology and perseverance. Dr. Anil Bhardwaj had delivered an enriching and patriotic speech to the audience, showcasing PRLs Scientific & other activities undertaken during the year. This was followed by merit and service awards to CISF Cadets.

In remembrance of our heroes and freedom fighters who sacrificed their lives for the nation, bringing us freedom, peace, and joy, a fancy dress programme for kids of PRL members was organized. The age group was 2-17 years, wherein several kids dressed as Mahatma Gandhiji, Rani Lakshmi Bai, Subhash Chandra Bose, Dr. B R Ambedkar, Bhagat Singh, Rani Velu Nachiyar, Sardar Vallabhbhai Pate, Pandit Jawaharlal Nehru, etc. These kids delivered a short speech about the national heroes portrayed by them. Dr. Anil Bhardwaj, Director, PRL encouraged them all by awarding them trophies and chocolates.

Post this, solo singing, solo dance, poem recitation, and group dances were performed by the PRL members and their family members. Their performances were dedicated to the martyrs who spend their lives, in their service to the nation. It enriched the feeling of patriotism in everyones heart.

Tri-color balloons were also released by the children to mark the day of Independence. To contribute to the environment, tree plantation was done by the Kids of PRL members and their families.

COVID Vaccination Amrit Mahotsav-II

As a part of celebration of Azadi Ka Amrit Mahotsav, DOS has informed all the centres to arrange free precaution dose against COVID for all eligible employees & their dependents as per guidelines of Government of India. In this connection, the COVID Vaccination camp was organised by Dispensary & Medical Cell PRL in association with Ahmedabad Municipal Corporation at Dispensary, Navrangpura Campus on 16th August, 2022 (Tuesday) from 10 am to 1 pm.

Google form link was created and circulated through allurers email for pre-registration. 148 beneficiaries had registered their names for vaccination. To avoid mass gathering at camp, prior information was given to all registered beneficiaries through email about allocation of different time slot for covid vaccination. During Camp, 163 eligible employees and their dependents were given precautionary dose of Covid Vaccine.

Dispensary & Medical Cell PRL wishes thanks to all to make this camp activity successful.

OBSERVENCE OF SADBHAVANA DIWAS

As per the directive of Government of India, Department of Space, the 20th August the birth anniversary of Late Shri Rajiv Gandhi is observed as SADBHAVANA DIWAS to promote national integration and communal harmony among people of all religions, languages and regions. The PRL members observed the Sadbhavana Diwas at ones own work place on Thursday, the 18th August, 2022 at 1100 hours, by reading the Sadbhavana Pledge.

Garba Celebration at PRL

Navratri is one of the major and important festivals, celebrated to worship the Goddess Durga. Navratri celebration was organized at PRL Thaltej Campus on Saturday, the 1st October, 2022.

The PRL staff members including trainees, research scholars and students participated enthusiastically. Everyone was Dressed up in

traditional wear clothes like chaniya cholis and kurtas. The event started with the Aarti by the Director, PRL and other PRL members. The prasad was distributed to everyone. Mementoes were presented to all the kids below 10 years of age. Thereafter, the Garba event started. Two judges were nominated for evaluating the garba players based on their costume, garba steps styles and how long they play garba. Category wise prize distribution was done at the end. Everyone enjoyed the event thoroughly.

Promotion of Khadi at PRL

Gandhi Jayanti is celebrated annually on the 2nd of October to commemorate the birthday of Mahatma Gandhi. In order to celebrate this, instructions were received from DOS Letter No. A.24011/1/2006-I dated 12.09.2017 to promote Khadi and support Khadi sector/ products.

Azadi Ka Amrit Mahotsav committee at PRL has issued an Appeal to PRL members to visit the nearest Khadi Shop and buy Khadi materials/fabrics/other consumer products, especially in view of the festival season. There exists an online (https://www.kvic.gov.in/kvicres/index.php) shopping platform to buy Khadi products.

Further, a "Khadi Exhibition" was arranged by the Space Application Centre (SAC) at the Community Hall, Vikramnagar Colony, Ambli-Bopal Road, Ahmedabad during 06-08 October 2022. For this, all PRL members were informed and requested to visit the Exhibition and promote the use of Khadi.

Cleanliness Drive at PRL Campuses

Gandhi Jayanti is celebrated annually on the 2nd of October to commemorate the birthday of Mahatma Gandhi. As a part of this, a cleanliness drive was organized on Tuesday, the 4^{th} October, 2022 under Azadi Ka Amrit Mahotsav. The cleanliness drive started from PRL Nursery Main campus. This activity is titled as " .

The PRL staff members including trainees, research scholars and students participated enthusiastically.

During the drive, the main focus was to pick up the plastic waste from the campus and to make the campus clean.

An active and enthusiastic participation was witnessed in the drive. The staff members also discussed about keeping separate bin on each floor of the office, to collect the non-useful of waste paper, which can further be collectively transferred to store for selling or shredding. The Co-chair made daily-wages aware about the importance of cleanliness and urged them to follow the same in- side the campus. PRL Thaltej Campus A cleanliness drive also was conducted at PRL Thaltej campus on 4th October, 2022. The cleanliness drive started from old building admin foyer. The PRL staff members including senior professor, trainees, research scholars, students and contractual workers all participated enthusiastically. Main focus of drive was to pick up scattered plastic pieces from the campus. The drive ended at staff canteen. The suggestion also came from member that similar drive should be organized for PRL staff quarters.

PRL Mt. Abu Campus

A Cleanliness drive in PRL Mount Abu Campus was carried out on 10.10.2022 Monday. The PRL Staff members including trainees & contractual staff participated in this program. The motive was to collect all the waste & dirt items from outside the main gate at Hill View campus and thrown them into the dust bin. Sweeping inside the premise to make the campus neat & clean.

World Space Week Program at PRL

World Space Week is an international celebration of science and technology, and their contribution to the betterment of the human condition. The United Nations General Assembly declared in 1999 that World Space Week will be held each year from October 4-10. These dates commemorate two events: These dates commemorate two events: October 4, 1957: Launch of the first human-made Earth satellite, Sputnik 1, thus opening the way for space exploration. October 10, 1967: The signing of the Treaty on Principles Governing the Activities of States in the Exploration and Peaceful Uses of Outer Space, including the Moon and Other Celestial Bodies. The Theme of this years (2022) World Space Week celebration is celebrating sustainability in space, and sustainability from space.

Under the continued celebration of Azadi ka Amrit Mahotsav (AKAM) at PRL, the AKAM committee jointly with Hindi Month Program committee organized a popular talk on the theme of the World Space Week and Hamara Karya at PRL on 07 October 2022. Matching with the theme of this years World Space Week celebration, Prof. D Pallamraju, Senior Professor and Dean at PRL, Ahmedabad delivered a popular talk on Understanding Space Weather: An essential part of ensuring Sustainability on Earth : .

About 150 students (Classes 8th, 9th and 11th Science stream) and some BSc/MSc level students from different schools and colleges of Ahmedabad and members of PRL took part on this program. Along with the importance of space research students also learned about various research being undertaken at PRL. The students very enthusiastically participated in interactive discussion with the basic and curious scientific questions on space science and research and their importance in our day-to-day life and understanding of Sun-Earth interaction.

As a part of Azadi Ka Amrit Mahotsav under which Hindi Maah was celebrated in conjunction with the Celebration of World Space Week from October 4-10, 2022, and the platinum jubilee of PRL, the following two events were organized at PRL.

1. Varg Paheli (Crosswords) Competition was organized on Monday, 3rd October, 2022 at 1400 hrs. The competition was organized in the NanoSIMS Auditorium of PRL Main Campus, Thaltej Seminar Room No 113, Seminar Hall of USO, and Observatory Control Room of Mt. Abu simultaneously. In this competition, 73 PRL members participated from all the PRL campuses. This competition was evaluated in both Hindi & Non- Hindi categories.

2.Word Quiz (Shabd Prashnottari) was organized on Monday, 10th October 2022 at K R Ramanathan Auditorium, wherein a total of 9 teams from various Areas, Divisions & Services participated.

The questions in both events were comprised of Space Science & Technology Achievements of India/DOS/ISRO/PRL, Hindi language, general knowledge & so on. PRL members participated

enthusiastically.

National Unity Day

National Unity Day or Rashtriya Ekta Diwas is celebrated every year on 31st October, since 2014 to mark the birth anniversary of the Iron Man of India Sardar Vallabhbhai Patel. This year marks the 147th birth anniversary of the freedom fighter. Sardar Patel played a major role in the integration of India (Ek Bharat) from over 560 princely states. To acknowledge his efforts in uniting the nation, India celebrates National Unity Day on his birth anniversary.

To celebrate the birth anniversary of Sardar Patel and National Unity Day, the Committee for Azadi ka Amrit Mahotsav, PRL organized the "Cycling, Running, Prabhat Pheri - For UNITY" on 30th October 2022 (Sunday). All members of PRL (Permanent staff members, Research Scholars, Project Associates, Post-Doctoral Fellows, Trainees, contractual manpower) and family members were invited to join the campaign as per their preference/convenience. The Team of Students of PRL led this campaign under CAKAM.

Cycling (10 Km) and running (5.5 Km) started around 06:45 am from the PRL Thaltej campus and finished at PRL main campus. After that all members present there started Padyatra from PRL main campus, walking towards Gujarat University, Panjarapole, IIM, and back to the Main campus (3 Km). The total number of participants was 25, 12, and 110 in Cycling, Running, and Padyatra respectively.

This significant program engraved the spirit of Ekta amongst all the participants.

C-AKAM Special Lecture on "International Day for the Elimination of Violence against Women" - Special lecture on 25th November 2022 for PRL women members

A special lecture cum interactive session was organized for women employees and women CHSS beneficiaries on 25-11-2022 at 4 PM in K R Ramanathan Auditorium, PRL by CAKAM in coordination with ICC & Women Cell PRL.

Around 86 members participated from Main Campus, Thaltej Campus and USO (through web link). Program began with opening remarks about the subject by Mrs. Nandini Rao. Professor Lokesh Sahu, Chairman- AKAM addressed the gathering and mark the launch of campaign on 25 November 2022 with main objective to eliminate violence against women. Prof. Sahu also spoke about the Global theme regarding gender-biased violence UNiTE! Activism to end violence against women and girls.

Prof Srubabati Goswami and Chair, Women cell who works at National and International level for empowerment of female employees addressed the gathering. Prof. Srubabati emphasised that the violence against women and girls remains the most pervasive human rights violation around the world and to reduce and prevent violence against women and girls, and protect their rights. She also added that the domestic violence is seriously under reported and lack of support from the family worsens the situation.

Dr. Shital Patel delivered the Special lecture and provided the information about types of violence, violation of human right, measures to avoid violence and suggested helpline numbers for rescue in such cases in India. She also spoke about the schemes undertaken by the Govt. of India, to provide support to the victims. She ended her talk by emphasizing to take a pledge to prevent domestic violence. The talk was followed by a question-and-answer session. The following were proposed:

1. To conduct workshops for small groups of male and female. 2. Going to the schools in nearby villages to sensitize adolescent girls. 3. Women counselling workshops to be organized. 4. Self-defense workshops to be organized.

The ICC & Women cell shall look into these suggestions. To mark the Constitution Day 26th being a weekend holiday) Ms. Jayashree Balan Iyer read out preamble of the Constitution, which was followed by Vote of Thanks by Mrs. Rumkee Dutta. The session was concluded with National Anthem.

Death Anniversary of Late Prof. Vikram A Sarabhai and Late Prof. K R Ramanathan

On the commemoration of the founder of Physical Research Laboratory, Late Professor Vikram A. Sarabhai and the founder Director of PRL, Late Professor K.R. Ramanathan, reverence was offered at the Foyer area of K R Ramanathan Auditorium on Friday, 30.12.2022.

A two-minute silence was observed in remembrance of Profs. Sarabhai and Ramanathan who had contributed immensely in the field of science. Followed by this, Prof. D Pallam Raju, Dean, PRL addressed the PRL members and shared the visions on the vital scientific contributions of Late Professor Vikram A. Sarabhai and Late Professor K.R. Ramanathan in Indian perspective and in particular to PRL. Thereafter, PRL members paid floral tribute to Late Professor Vikram A. Sarabhai and Late Professor K.R. Ramanathan.

Treasure Hunt Competition

Treasure Hunt Competition organized by C-AKAM at PRL. On the occasion of the 74^{th} Republic day and in continuation to the celebrations under Azadi Ka Amrit Mahotsav (AKAM), a Treasure Hunt event was organized at PRL Thaltej Campus on 26/01/2023. This event was devised with the idea to make all participants aware of various facilities, labs, nooks, and corners of the Thaltej Campus of PRL. In total 105 participants including permanent staff, research scholars, project associates, post-doctoral fellows, Trainees, and their family members parents/spouses/kids (kids of age 10 years and above) took part in the event. The participants were divided into 20 teams and provided with links to clues managed through a google form. Each team was given out a unique trail covering the entire campus. The clues were thoughtfully assigned unique ids with the names of constellations and famous Indian Scientists. Each team was required to reach their designated locations and upload a selfie of the group at that location. Once uploaded, the team got the next clue using the google form. The teams who could complete the hunt correctly in minimum time were the winners. This event turned out to be a grand success with the help of committed volunteers.

C-AKAM Book Exhibition at Thaltej Campus 26 January 2023

The Library organized a book exhibition as a part of the AKAM activity at the Old Building Foyer, Thaltej Campus on 26-27 January 2023. There were around 600 scientific, general, and Hindi books on display by three booksellers. The in-campus exhibition helps the staff to browse through many books in their area of interest which are a useful addition to the library collection. The exhibition attracted active participation from research scholars, staff, and faculty members of PRL. There were 194 books recommended by them for the library and 4 books for personal use. The event was well received by research scholars, staff, and faculty members of PRL.

Martyr's Day

As per the Government of India, Department of Space directive, the 30th January is observed as Martyrs Day in memory of those who sacrificed their lives during struggle for Indias freedom. PRL members observed 2 (two) minutes of silence in memory of freedom fighters on Monday, the 30th January, 2023 at ones own work place.

Swachhta Pakhwada

The Swachhta Pakhwada was celebrated at Physical Research Laboratory (PRL) from 1st to 15th February 2023 as per the directives received from Director CEPO/ Nodal Officer, SAP on Swachhta Action Plan 2023-24, wherein, it states that Swachhta Pakhwada is to be organized from 1st to 15th February 2023 in the Department of Space and DOS Centres/Units with the main focus on Hygiene and Sanitation.

As a part of Swachhta Pakhwada, PRL members undertook the Swachhta Pledge/Shapath on 01.02.2023. All the staff members were advised to commit to eliminate the excessive and uncontrolled use of plastic in day-to-day official work as accumulation of plastic waste is posing a threat to the global environment. As a part of Swachhta Pakhwada Campaign, fogging and fumigation was done during the Pakhwada period in all the campuses of PRL as well as residential colonies. Further, it would continue as routine activity throughout the year.

In order to maintain cleanliness and hygiene, cleaning of water bodies like GLR & OHT, sewer lines and artificial ponds at the office campuses as well as residential colonies took place at regular intervals. A cleanliness drive was carried out at Mt. Abu campus. During the Swachhta Pakhwada- 2023, a special emphasis was given for weeding out of records/ disposal of non-useful furniture/ instruments which are beyond economic repair, for which all Division Chairs & Heads had taken lead and action was taken with proper procedure of weeding out.

PRL is dedicated to promoting and spreading the message of cleanliness, hygiene and sanitation. At PRL's campuses in Ahmedabad, Mount Abu, and Udaipur, including observatory sites, we prioritize in maintaining a clean and green environment. We believe that a clean and healthy environment is essential for the well-being of all living beings. Our commitment to cleanliness extends beyond the physical infrastructure of our campuses. PRL members are also committed to contributing to the cause of cleanliness in their personal and professional lives.

We encourage and promote responsible waste management practices, including reducing, reusing, and recycling waste wherever possible. We also educate and raise awareness among our staff and students on the importance of cleanliness and hygiene.

International Women's Day Celebration

In concurrence with the directives received from the DOS, International Womens Week was celebrated from 1 st to 8 th March 2023 and International Womens Day on 15 th March 2023. A day wise description is as follows:

- From 1 st to 8 th March 2023, a poster competition on the theme "Stop Domestic Violence" was organised by the Women Cell at PRL. The posters were to be prepared in Gujarati, Hindi or English. The received posters were displayed in Lift foyer during 01-08 March 2023. These posters were evaluated by a team of five judges and best three were selected. Additionally, a "give your thoughts" board was set up to portray the thoughts on women's empowerment and feedback from the visitors.
- On 1st & 2nd March Self-Defense sessions by Ms Shreya Mishra for women members at Navrangpura and Thaltej Campus were organised and basics of self defense were taught.
- On 6th March - An awareness programme by Dr Shital Patel on Violence against women for the contract staff at Navrangpura Campus was organised.
- On 7th March - Bibha Chowdhuri Memorial Lecture by Dr. Rama was organised.
- On 15th March - IWD celebration was organised and a short cultural programme followed by a talk by Prof. Anjana Vyas on "DigitALL: Innovation and technology for gender equality".

In addition, a charity distribution was carried out at Ahmedabad and USO Campuses where grocery items and school related items (tiffin boxes and bottles) were distributed to needygirls/women. PRL also gifted a bag as a token of appreciation to all its Women employees.

Annual Badminton Tournament for the year 2022-23.

As part of the celebrations for Azadi ka Amrit Mahotsav, the PRL (Physical Research Laboratory) Staff Welfare Committee organized the annual Badminton Tournament for the 2022-2023 season on the 4th and 5th of February, 2023. The tournament provided a platform for PRL staff members to showcase their skills and compete against one another in a friendly and competitive atmosphere. The tournament was inaugurated by Dr. Anil Bhardwaj, the Director of PRL, who wished all the participants good luck and encouraged them to play with sportsmanship and camaraderie. The event saw enthusiastic participation and the matches were closely contested with thrilling displays of athleticism and skill. The tournament witnessed many nail-biting, fun-filled, and highly competitive games spanning various formats like Singles, Doubles, Team events, and Lucky Doubles. This year, the overall participation in the tournament was overwhelming, with around 50 participants taking part in various events, spanning nearly all the areas of PRL including participants from Udaipur Solar Observatory, Udaipur. The Badminton Tournament was a highly anticipated event, with a large number of enthusiastic spectators turning up to support their favorite participants.

Annual Table Tennis Tournament for the year 2022-23

Physical Research Laboratory is dedicated to fostering talent and providing opportunities for its staff and researchers from diverse backgrounds. As we celebrate Azadi ka Amrit Mahotsav, we are proud to continue this tradition by organizing our annual Table Tennis tournament during 11th and 12th March 2023.

The tournament was inaugurated by Dr. Anil Bhardwaj, the Director of PRL, who wished all the participants good luck and encouraged them to play with sportsmanship. Thetournament witnessed many nail-biting, fun-filled, and highly competitive games spanning various formats like Singles, Doubles, Team events, Mix-Doubles, and Lucky Doubles. This year, the overall participation in the tournament was overwhelming.

This year, 36 staff and researchers, including 30 men and 6 women, enthusiastically participated in the tournament, showcasing their skills and camaraderie. The cheering and applause from the crowd added to the excitement and created a lively atmosphere throughout the two days event. As the great Arthur Ashe once said, "Success is a journey, not a destination. The doing is often more important than the outcome." We congratulate all the participants and winners, and look forward to continuing to support their journeys towards success."

C-AKAM team had developed a bilingual, secure, and responsive web portal dedicated to the celebration of Azadi Ka Amrit Mahotsav at PRL. The web portal, accessible at `https://www.prl.res.in/~c-akam`, which provides comprehensive information and activities related to the event. The portal ensures a user-friendly experience while maintaining a high level of security.

Republic Day Celebration at PRL—2023

The 74th Republic Day was celebrated on 26th January, 2023, at Physical Research Laboratory Thaltej campus. Dr. Anil Bhardwaj, Director, PRL hoisted the National Flag followed by the National Anthem. In his address to PRL family, the Director briefed about the various events, activities, achievements, honours etc. acquired by PRL during the year. Three merit awards were given to the Central Industrial Security Force (CISF) personnel. Service Awards to PRL staff members who have completed 25 years of services in PRL were also presented. This was followed by presentation of the Awards to: (a) The children of PRL staff who secured Highest marks in Hindi subject in 10th and 12th standard during the year 2022. (b) Space Official Language Implementation Scheme (SOLIS) related prizes (c) Hindi Speech Competition (Vishwa Hindi Diwas) and (d) Quiz competition held during Vigilance Awareness Week 2022. Tree-plantation was done by the newly joined PRL Staff Members, Awardees, would-be-retirees of the year and other PRL members at open ground of the Campus. As a symbol of freedom & growth of our Country & Institute to sky heights, Tri-color balloons were released on this occasion. Kids enjoyed this event at optimum.

Treasure Hunt Competition at USO / PRL, Udaipur

On the occasion of 74th Republic Day, a treasure hunt competition was organized for all the permanent employees & their family members, research scholars, PDFs and trainees at USO/PRL, Udaipur under the Azadi ka Amrit Mahotsav. Under this program all the participants were divided into various groups (teams). In order to maintain balance in the selection of teams, equal number of staff members & family members, research scholars / PDFs and trainees were placed in each team so that all team members have equal participation in understanding and recognizing technical and common clues. Different clues were given to each team. Each clue was interconnected in such a way that solving the first clue could lead to the second clue. Along with each clue, some souvenirs were kept by which their curiosity can be maintained. After finding all the clues, each team had to reach the canteen. The first three teams to reach the canteen after finding all the clues were declared as the first, second and third winners respectively according to the time taken by them.

Visit of Students from R.N.T P.G. College, Kapasan, Chittorgarh

A group of students along with faculty members from R.N.T. P.G. College, Kapasan-312202, Chittorgarh visited Udaipur Solar Observatory on 24/01/2023. The group included students from B. Sc. and M. Sc. Physics background. The group visited Island Observatory, GONG and e-CALLISTO facilities of the Udaipur Solar Observatory. They were informed about different aspects of the Sun, solar activity and the multiwavelength observations of the solar atmosphere.

A one day meet on "PRL's 75 years science journey and our role" by PRL Alumni

A growth of an institution is best evaluated by the career-path of its alumni. PRL has produced $\sim$500 alumni in last 75 years and many of these have reached to serve at the top level of different institutions in India and worldwide. Ongoing platinum jubilee celebrations gave an occasion to reflect our legacy and the contributions we have made to science. Inauguration of this one-day conference, held on the 30th of January, 2023, was started with the welcome address by our patron, Prof. Anil Bhardwaj, Director, PRL; followed by a historical perspective given by Prof. Sunil Kumar Singh, President, PRL Alumni Association. The occasion was graced by PRL's one of the most illustrious alumni Prof. K. Kasturirangan, who inspired each one of us by talking about "My Professional Forays - People, Challenges & Anecdotes". There were four talks by relatively young PRL alumni, who shared their exciting science. There was a fruitful and informative panel discussion on "Science in transition fundamental science to citizen science" moderated by Prof. R. Bhutani in which Profs. Sunil Singh, JS Ray, D. Pallamraju, A. Tej, and E. Krishnakumar shared their thoughts. The meeting was attended by almost 100 PRL alumni and some of their family members also joined.

Public lecture on "Indian Planetary and Space Missions"

As a part of 7 th National Symposium on Shock Waves (NSSW-2023), a public lecture on Indian Planetary and Space Missions was delivered by Prof Anil Bhardwaj, Director, PRL on 15th February 2023. This public lecture was attended with great interest and curiosity not only by the delegates of the symposium, but also the shock wave research community and general public with prior online registration. An interactive question and answer session followed the lecture.

Capacity Building Programmes

Karyashala "Astrochemistry and Cratering in Solar System" & Asteroid Day @ PRL

This unique workshop is designed to show the interdisciplinary nature of the research areas Astrochemistry and Planetary Remote Sensing and an effort to try to attract more young minds to choose this area of research in their science career. About 14 research/master degree students participated where their current area of work ranges from Geology / Applied geology, Geophysics, Physics, Chemistry / Astrochemistry and are also from different parts of the country.

The workshop had lectures by experts in the area of astrochemistry and planetary remote sensing, atomic and molecular physics, geology and biophysics as the workshop briefly touched on astrobiology a closely associated subject to astrochemistry. In addition, we had hands on session for the participants almost every day during the workshop. They had the opportunity to see how the deep space and solar system conditions were brought in the laboratory and the physico-chemical nature of molecular ices were studied. They had the opportunity to take part in the experiment in our unique High Temperature Shock Tube for Astrochemistry (HISTA). Hands-on session on Moon and Mars datasets extraction, data analysis and interpretation were part of the catering in solar system module.

Day 1 The workshop wsa inaugurated by Dr. Anil Bhardwaj, the Director of PRL, followed by talks from Dr. Varun Sheel, HoD, PSDN and Dr. R P Singh, HoD, AMOPH was there. The first lecture was on Geology of the Moon Remote sensing Perspective. The lecturer gave a brief description about the cause for origin and evolution of the solar system, which was Meteoritic impact and Volcanism.

Day 2 - started with online talk on Challenges in conducting astrobiology research Astrobiology, space biology, Gaganyaan, Concept of Bioastronautics, Use of Engineering and technology to facilitate healthy human inhabitation of space were discussed. The second online talk was on Astrochemistry- simple to complex molecules; and explained about Drake equation, Kepler mission, Murchison meteorite, various astrochemical models and biomolecules. The third talk was on Role of water in shaping Mars.

Day 3 First lecture was on Chemical and Biological crystallography in Space Science where he discussed about, X-ray crystallography, SCXRD and Insitu-cryo crystallization etc. After the lecture, hands-on session with the astrochemistry experimental facility housed in PRL - like HISTA and SALT.

Day 4 - began with hands on session of SALT, HISTA instruments; followed by a lecture on Indian Meteorites. The talk briefly explained on how to identify a meteorite from other rocks. Then we had a presentation on Microgravity and shock processing respectively. Later an online lecture on Remote sensing Dataset for technical analogues in which all aspects of remote sensing were covered.

Day 5 The first lecture was on Targeting Craters in which the various criteria to identify a crater were explained. Followed by Hands-on session on Sittampundi anorthosite and meteorites was carried out. The second talk of the day was on Mechanical behaviour of meteorites and their importance of correlation - multiscale behaviour of meteorite samples. Then a lecture on Electron Induced Processes for Molecules of Titan. The lecturer conveyed that a well-studied environment that is believed to provide a mimic for a prebiotic Earth is Titan.

Day 6 The first lecture was on Terrestrial Analogues for planetary Exploration with special reference to Mars and Moon. Rest of the day the participants were busy with the hands-on session on low and high temperature astrochemistry and 3D printing in preparing the posters related to the Asteroid day.

Day 7 (10 July) This day was celebrated as Asteroid Day @ PRL. The PRL Thaltej campus was open for the visitors and almost 600 people including children, their parents and the PRL employees with family visited the event. The visits of unique laboratories that are present in the PRL Thaltej campus were part of the event along with the geological samples display and real asteroid samples (meteorites) display.

Student Conference on Optics and Photonics (SCOP-2022)

Azadi Ka Amrit Mahotsav is an initiative of the Government of India to celebrate and commemorate 75 years of independence and the glorious history of its people, culture, and achievements. PRL celebrated Azadi Ka Amrit Mahotsav by conducting various events throughout the year. On this occasion, the PRL Student Chapter organized its annual conference SCOP 2022 during 28-30 September 2022. It was a three days conference, organized by the students and participated by the research fellows and post-doctoral fellows from different parts of India. SCOP-2022 was attended by 70 research fellows and post-doctoral fellows from 25 different Institutes/Universities and 30 in-house participants. To broaden the perspective of the participants, the conference hosted twenty-five invited speakers from different Institutes of India working on different fields including planetary science, atmospheric science and Astronomy and Astrophysics, and a popular lecture by the Director of PRL, Prof. Anil Bhardwaj, a world renowned planetary scientists. Due to this annual conference, the M.Sc., PhD and postdoctoral students from different parts of India got the opportunity to visit PRL and share their research and build networking among themselves. As part of PRL outreach activities, different laboratories working in Optics were made available for the visit of the conference participants. On the other hand, this conference also enables PRL research fellows to build leadership and organizational qualities. In its seventh year, the conference has marked its position among the students and faculties in India and abroad.

CSSTEAP Short Course on Space Weather

A short course on "Space Weather" was conducted during December 20-30, 2022 by Physical Research Laboratory under the auspices of Center for Space Science and Technology Education in Asia and the Pacific (CSSTEAP), affiliated to the United Nations. The inaugural ceremony was held at PRL on 20th December. There were 21 participants from 11 countries (Bangladesh, Ethiopia, India, Kazakhstan, Kyrgyzstan, Mongolia, Myanmar, Nepal, Sri Lanka, Tajikistan and Uzbekistan). Classes were held at Nano-SIMS hall. A total of 25 lectures were delivered by PRL's expert faculty on:

- Solar sources of space weather
- Propagation of the electromagnetic and charged particles through the heliosphere
- The response of Earths magnetosphere, ionosphere and thermosphere to Space Weather
- Solar influence on middle atmospheric processes
- Effect of Space Weather on electronic and communications systems For a better understanding of the theory

There were practical sessions on:

1. Measurement of the speed of coronal mass ejection
2. Measurements of sunspots
3. Measurement of the geomagnetic field
4. Radio sounding of the ionosphere
5. Measurements of TEC and scintillation using GPS
6. Study of optical signatures of space weather events.

As a part of the programme, the participants were taken to Udaipur Solar Observatory (USO) and Mount Abu Observatory for a very short scientific tour. The trip to USO started with a visit to MAST, the Multi-Application Solar Telescope installed on the island in Lake Fatehsagar. They also visited the GONG (Global Oscillation Network Group) and e-Callisto facilities in the main campus. At Mt Abu Observatory, the students observed Jupiter through the telescope. Feedback from the participants was very positive.

Venus Science Conference (Venus-SC-2022)

Researchers have been working in the area of planetary sciences for many decades and explore various planets like Venus, Mars, Jupiter, Saturn etc. However, Venus, the sister planet of Earth, has been of interest to space scientists for different reasons. There are some open research problems like evolution of Venusian surface, unknown UV absorber, lightning, super-rotation and space weather on Venus. The observations on Venusian science has been from the time of Venera in 1960s and many missions like Mariner, Pioneer Venus, Vega, Magellan, Venus Express, Akatsuki, IKAROS have provided lots of data to the community. In addition, other unintended missions like Galileo, Cassini, MESSENGER, Parker Solar Probe, BepiColombo and Solar Orbiter have also given flyby observations of Venus. The data analysis from the missions bring different scientific outcomes related to planet Venus and appear in the literature. Some conferences are organized over the globe to discuss the Venusian science, either within a planetary conference or as a dedicated conference.

The Physical Research Laboratory (PRL) has organised the second conference on Venus Science, Venus-SC-2022. The conference was convened by Dr. Jayesh Pabari during 29-30 September 2022 (online). It focused on modelling, observations, data analysis, conceptual instrument design and scientific experiments for Venus exploration. The major research areas covered in the conference were surface, atmosphere, clouds, GCM, lightning, airglow, habitability, ionosphere, interplanetary dust, and solar wind interaction with the planet. Such gathering provides an opportunity to interact among the community over the globe and also, collaborate with people working in similar fields over a period of time.

More than 172 delegates had registered for the conference, which included speakers for oral presentations, short oral presentations and other attendees. The oral presentations had 24 talks from universities/institutes outside India and 15 talks from Indian institutions. The short oral presentations have 18 talks from India institutions. A few examples of the talks are Great Climate Transition, Cloud Particle Sample Return, Balloon and In-Situ Missions, Akatsuki Results, Lightning and whistler waves, Venusian GCM, Atmospheric Escape, Radio Occultation Experiments and Interplanetary dust inside 1 AU. This year, we have included a dedicated session on Venusian data analysis for those, who are interested to carry out the data analysis in future.

The outside India included universities/institutes from places like US, UK, Japan, Sweden, South Korea, Taiwan, Germany, France and Norway. The centres/institutes from within India covered SAC, IIRS, SPL, PRL, CHARUSAT, Amity Uni., NARL, St. Xaviers College, IITB, IISER, NISER, Uni. Allahabad and Panjab Uni. The Venus Science Conference included speakers spanning 4 time zones.

Honourable Shri A. S. Kiran Kumar (Council Chair, PRL) and Honourable Prof. Anil Bhardwaj (Director, PRL) had graced the inaugural session. There were 7 sessions covering all mentioned research areas. The session chairs were well experienced in the domain and they were from various ISRO/Non-ISRO centres. There was a concluding session at the end of the conference. Many people including Prof. Anil Bhardwaj (Director, PRL), Prof. D. Pallamraju (Dean, PRL), the SOC and LOC members, extended LOC members, Dr. Bhushit Vaishnav (Head, Academic Services), Shri Dinesh Mehta, IT team, electrical team and other members had helped as and when needed for the conference.

IPSC Workshop 2023

Research in the areas of planetary sciences cover topics like solar system origin and evolution, planetary geology, planetary atmospheric, interplanetary dust dynamics, effect of solar wind, analogue sample study in laboratory, data analysis, instrumentation etc. The Indian Planetary Sciences Association (IPSA) has organized a two day workshop on Planetary Exploration: Going Beyond!!. The workshop was convened by Dr. Jayesh Pabari during 20-21 March 2023 at Physical Research Laboratory, Ahmedabad. The workshop aimed at motivating bright and talented young minds from Indian universities, colleges and academic and research institutes, to take up a career in Planetary Exploration. The workshop consisted of lectures by subject experts, tutorials, hands-on and laboratory visits.

Total 350 applications were received from which, 52 students were short listed from different parts of the country. The purpose of the workshop was to make the students aware about the planetary sciences. Honourable Prof. Anil Bhardwaj (Director, PRL), Prof. D. Pallamraju (Dean, PRL) and Prof. R. D. Deshpande (Registrar, PRL) had graced the inaugural session. Students presentations on out-of-the-box topics were arranged on the second day and the workshop ended with a concluding session. Many people including Prof. Anil Bhardwaj (Director, PRL), Prof. D. Pallamraju (Dean, PRL), Prof. R. D. Deshpande (Registrar, PRL), the LOC members, extended LOC members, IT team, electrical team and other members had helped as and when needed for the workshop.

4th PRL Conference on Condensed Matter Physics (PRL CCMP 2023)

The 4th PRL Conference on Condensed Matter Physics, a three day national conference was held at PRL Navrangpura campus from 6-8 February 2023. to discuss recent developments in condensed matter physics, particularly superconductivity, topological quantum matters, strongly correlated systems, and material science with space applications. The conference was held in person. This is a biannial conference organized PRL. It is one of regular focused meetings for the overall development of the community especially for the students and other young researchers. There were 100 participants including faculty members, scientists, postdoctoral fellows, Ph.D. students, and Master students from various research institutes, IITs, IISERs, Universities and colleges across India. There were 4 keynote talks by senior faculty members, 15 invited talks by senior and young faculty members, and 5 contributed talks by young faculty members and senior Ph.D. students on the above-mentioned topics. There was a marathon display poster session where all poster presenters flashed their posters/presentations in two minutes. This session was very popular among the participants since they utilized it to attract the audience to visit their posters during the poster sessions. There were two dedicated poster sessions with sufficient time for interactions. A competition on poster presentation was held and judged by six faculty members including theorists and experimentalists and experts of different fields. There was an evening talk on air pollution and Climate change. The meeting was well-appreciated by all the participants including seniors. The key points of the discussions according to the major topics of the conference are as follows: Superconductivity: Vortex pinning, NbSe2, Higher-Order topological superconductors, twisted bilayer graphene. Topological Quantum matters: Non-abelian anyons, transport in Dirac semimetal, topological defects in Graphene, Moire systems, quantum geometric effects, SSH model with a non-orientable bulk. Strongly correlated systems: Density of states of insulators, non-Kramers quantum Spin-Ice. Material science: Twisted bilayer graphene, antiferromagnet/non-magnet heterostructure, vander Waals ferromagnet, Quantum Materials beyond the realms of Gross-Pitaevskii Equation. Others: Dipolar bosons in a multilayer optical lattice, oceans of water deep in the Earths mantle, ultracold gasses. During the valedictory session of the conference, four students were awarded Wolfram Award for top four poster presentations. The winners and the titles of their presentations are as follow. 1. Ms. Ritwika Majumder, NISER Bhubaneswar India - Monte-Carlo exploration of generalized Kitaev model on a square lattice. 2. Mr. S. Roy, IIT Madras, India - Domain Wall Effects in Unconventional Superconductors 3. Mr. Basabendra Roy, IISER Kolkata India - Competing ultrafast energy relaxation mechanisms in a zero hysteresis strongly correlated system. 4. Mr. Debashish Mondal, IOP Bhubaneswar - Generation of multiple anomalous Majorana modes in realistic model systems. We thank all PRL family members for their invaluable support and sponsors Wolfram Inc., Balani Group and IOP publishing for partial financial support in making the event successful. We also thank all the participants of PRL CCMP for making this 4 th meeting a memorable and successful event.

7th National Symposium on Shock Waves (NSSW-2023)

The 7th National Symposium on Shock Waves (NSSW-2023) was organized at the Physical Research Laboratory (PRL) during 15-17 February 2023. The broad objective of this symposium was to disseminate and nurture the Science and Technology of Shock Waves and related area in the country as well as globally, under the aegis of The Society for Shock Wave Research (India). Prof Anil Bhardwaj, Director, PRL, welcomed the delegates of the symposium, that was inaugurated by Shri S. Somanath, Secretary, DOS and Chairman, ISRO through his pre-recorded video message. The symposium had 140 participants including 4 plenary speakers, 28 invited speakers, and rest oral presenters including MSc and PhD students, post-doctoral fellows, scientists and faculties for various laboratories including DRDO laboratories, and academic institutes including IITs, IISc and universities. In this symposium researchers deliberated on variety of topics related shock waves, ranging from the fundamental science of shock waves, its interactions and flow; to interdisciplinary applications for blast, biomedical, chemistry, astrochemistry and planetary sciences. Specific topics deliberated in NSSW-2023 included research from the trisonic to hypersonic, simulations of shocks experienced in hypervelocity impacts events in the solar system and the shocks in the interstellar medium. The dedicated session on the biomedical applications of shock waves was highly appreciated by the participants. In another session, the applications of shock waves to real time problems were discussed. Five best paper awards and an award for interdisciplinary research were given to the research students attending NSSW-2023.

RESPOND

Rohan Louis, Co-PI on 3-year ISRO RESPOND-Basket Project titled, 'Investigation of Solar Eruptions using Sub-photosphere Dynamics' (Ref. No.: ISRO/RES/2/437/21-22), with Dr. Ram Ajor Maurya (PI), NIT Calicut.

ISRO-RESPOND projects

Dibyendu Chakrabarty: Focal point/Co-PI two ISRO-RESPOND projects. Dibyendu Chakrabarty: Member, RESPOND review Committee, PRL.

CSSTEAP

Amitava Guharay: Delivered a lecture on the topic “Solar influence on middle atmospheric processes” for A short course on Space Weather organized by PRL under the auspices of CSSTEAP, affiliated to the United Nations, 20-30 December, 2022. Amitava Guharay: Supervised a pilot project entitled “variability of thermal structure in the lower and middle atmosphere” for the 12th course on Space and Atmospheric Science organized by CSSTEAP affiliated to the United Nations, April-June-2022. K. Venkatesh: Delivered two lectures and two practical courses in the “Short course on Space Weather” conducted by PRL during 20-30 December, 2022.

As a part of capacity building efforts PRL.

Scientific and Technical Staff courses

1. Mr. Padia GirishKumar D, National Cyber Exercise (NCX INDIA), National Security Council Secretariat (NSCS), New Delhi, 18-29 April, 2022.
2. Dr. Neeraj Rastogi, Online Workshop on Intellectual Property Rights (IPR) Workshop, Capacity Building Programme Office (CBPO), ISRO HQ, 26 Apr, 2022.
3. Dr. Rajesh Kumar, Online Workshop on Intellectual Property Rights (IPR) Workshop, Capacity Building Programme Office (CBPO), ISRO HQ, 26 Apr, 2022.
4. Dr. Rajesh Kumar Kushwaha, Online Workshop on Intellectual Property Rights (IPR) Workshop, Capacity Building Programme Office (CBPO), ISRO HQ, 26 Apr, 2022.
5. Dr. Naveen Chauhan, Online Workshop on Intellectual Property Rights (IPR) Workshop, Capacity Building Programme Office (CBPO), ISRO HQ, 26 Apr, 2022.
6. Dr. Goutam K. Samanta, Online Workshop on Intellectual Property Rights (IPR) Workshop, Capacity Building Programme Office (CBPO), ISRO HQ, 26 Apr, 2022.
7. Dr. Dibyendu Chakrabarty, Online Workshop on Intellectual Property Rights (IPR) Workshop, Capacity Building Programme Office (CBPO), ISRO HQ, 26 Apr, 2022.
8. Dr. Abhijit Chakraborty, Online Workshop on Intellectual Property Rights (IPR) Workshop, Capacity Building Programme Office (CPB) ISRO HQ., 26 Apr, 2022.
9. Dr. Shanmugam M, Online Workshop on Intellectual Property Rights (IPR) Workshop, Capacity Building Programme Office (CBPO), ISRO HQ, 26 Apr, 2022.
10. Dr. D. Pallamraju, Online Workshop on Intellectual Property Rights (IPR) Workshop, Capacity Building Programme Office (CBPO), ISRO HQ, 26 Apr, 2022.
11. Dr. R. D. Deshpande, Online Workshop on Intellectual Property Rights (IPR) Workshop, Capacity Building Programme Office (CBPO), ISRO HQ, 26 Apr, 2022.
12. Dr. M. G. Yadava, Training on Departmental Enquiry for Inquiry Officers/Presenting Officers, National Academy of Direct Taxes, Regional Campus, Bengaluru, 06-08 Jun, 2022.
13. Dr. Sachindranath Naik, Training on Departmental Enquiry for Inquiry Officers/Presenting Officers, National Academy of Direct Taxes, Regional Campus, Bengaluru, 06-08 Jun, 2022.
14. Ms. Rumkee Dutta, Official Language Orientation Programme-2022, Human Space Flight Center (HSFC), DOS, Bengaluru, 22-24 Jun, 2022.
15. Dr. T. A. Rajesh, Bengaluru Space Expo- 2022 (BSX-2022)- an International conference & Exhibition, BIEC, Bengaluru, 05-07 Sept, 2022.
16. Mr. Tejas N Sarvaiya, Bengaluru Space Expo- 2022 (BSX-2022)- an International conference & Exhibition, BIEC, Bengaluru, 05-07 Sept, 2022.
17. Dr. Shanmugam M, Engineers Conclave-2022, Jointly organised by ISRO & Indian National Academy of Engineering (INAE) at LPSC, Valiamala, Trivandrum, 13-15 Oct, 2022.
18. Mr. Manan Shah, Engineers Conclave-2022, Jointly organised by ISRO & Indian National Academy of Engineering (INAE) at LPSC, Valiamala, Trivandrum, 13-15 Oct, 2022.
19. Dr. Narendra Ojha, National Conference on ”Akash for life”, Uttaranchal University, Dehradun, 05-06 Nov, 2022.
20. Dr. K. Venkatesh, National Conference on ”Akash for life”, Uttaranchal University, Deharadun, 05-06 Nov, 2022.
21. Dr. Rajesh Kumar Kushwaha, Structured Training Programme (STP) on ”Opening of space sector for private players with the focus on space sector reforms introduced”, ISRO HQ, Bengaluru, 21-25 Nov, 2022.
22. Dr. Shanmugam M, Management Development Programme (MDP), ASCI, Hyderabad, 05-16 Dec, 2022.
23. Dr. Shubhra Sharma, Online MDP on ”Environment Leadership and Life Skills”, Indian Institute of Forest Management, Bhopal, 13-15 Dec, 2022.
24. Dr. Girjesh R. Gupta, 37th National Symposium on Plasma Science & Technology (PLASMA-2022), Indian Institute of Technology, Jodhpur, 12-14 Dec, 2022.
25. Dr. Amitava Guharay, Workshop on ”Space Situational Awareness & Space Traffic Management- Growing Concerns on Space Environment”, Organised by ISTRAC, ASI, IN-SPACe & NSIL at Sheraton Grand Hotel (Brigade Gateway), Bengaluru, 11-13 Jan, 2023.
26. Dr. Vishal Joshi, Workshop on ”Space Situational Awareness & Space Traffic Management- Growing Concerns on Space Environment”, Organised by ISTRAC, ASI, IN-SPACe & NSIL at Sheraton Grand Hotel (Brigade Gateway), Bengaluru, 11-13 Jan, 2023.
27. Dr. Girjesh R. Gupta, Workshop on ”Space Situational Awareness & Space Traffic Management- Growing Concerns on Space Environment”, Organised by ISTRAC, ASI, IN-SPACe & NSIL at Sheraton Grand Hotel (Brigade Gateway), Bengaluru, 11-13 Jan, 2023.
28. Dr. T. A. Rajesh, Climate Risk Management: Policy and Governance, Lal Bahadur Shastri National Academy of Administration, Mussoorie, 30 Jan - 03 Feb, 2023.
29. Mr. Arpit Patel, Miniaturization of Space Systems, ISRO Guest House, Devanahalli, Bengaluru, 06-10 Feb, 2023.
30. Dr. S. Ramachandran, A Resilient Future: Science and Technology for Disaster Risk Reduction, Lal Bahadur Shastri National Academy of Administration, Mussoorie, 27 Feb - 03 Mar, 2023.
31. Dr. Shital H. Patel, Joint International Conference- 2023 (JIC) Cardiovascular-Internal Medicine Symposium, GMERS Medical College, Sola @ Club 07, Off S P Ring Road, Ahmedabad, 06-08 Jan, 2023.
32. Dr. Dibyendu Chakrabarty, Enhancing Organizational Performance through Knowledge Management and HR Analytics, Space Application Center, Ahmedabad, 09-15 Feb, 2023.
33. Ms. Swetapuspa Soumyashree, Climate Change: Challenges and Response, Lal Bahadur Shastri National Academy of Administration, Mussoorie, 13-17 March, 2023.
34. Dr. Shubhra Sharma, Environmental Leadership and Life Skills (Women Component), Indian Institute of Management, Bhopal, 13-17 March, 2023.

35. Dr. Paramita Dutta, Environmental Leadership and Life Skills (Women Component), Indian Institute of Management, Bhopal, 13-17 March, 2023.
36. Dr. Santosh V. Vadawale, Lunar Gravitational Wave Meet, International Centre for Theoretical Sciences (ICTS), Bengaluru, 17-20 Apr, 2023.
37. Dr. S. Vijayan, Lunar Gravitational Wave Meet, International Centre for Theoretical Sciences (ICTS), Bengaluru, 17-20 Apr, 2023.
38. Dr. Neeraj Rastogi, 6th NISAR Science Workshop, Space Application Center, Ahmedabad, 20-21 Mar, 2023.
39. Dr. Som Kumar Sharma, 6th NISAR Science Workshop, Space Application Center, Ahmedabad, 20-21 Mar, 2023.
40. Dr. Narendra Ojha, 6th NISAR Science Workshop, Space Application Center, Ahmedabad, 20-21 Mar, 2023.
41. Mr. Rajiv Ranjan Bharti, 6th NISAR Science Workshop, Space Application Center, Ahmedabad, 20-21 Mar, 2023.
42. Mr. Virendra Kumar Padhya, 6th NISAR Science Workshop, Space Application Center, Ahmedabad, 20-21 Mar, 2023.
43. Mr. Jigar A. Raval, India-USA Joint Training Program on ”Coordinated Incident Response for APTs- Unhiding Hidden Cobra”, CERT-In, New Delhi, 20-23 Mar, 2023.

Administrative Staff courses

44. Mr. Femics George, Induction training programme for newly recruited Assistants/ UDC/ JPA/ Hindi Typists in DOS/ ISRO units, VSSC, Thiruvanthipuram, 16-27 Jan, 2023.
45. Mr. Abhishek Prasad, Induction training programme for newly recruited Assistants/ UDC/ JPA/ Hindi Typists in DOS/ ISRO units, VSSC, Thiruvanthipuram, 16-27 Jan, 2023.

Official Language promotion at PRL

Rajbhasha Activities held during April 2022-March 2023

The Physical Research Laboratory (PRL), being one of the premier Research Institute, is maintaining the outreach to different strata of work force and common people. This breeze of enthusiasm is maintained in the innovative ways of promotion Official Language activities too. Some of the noteworth acitivites held throughout the year are as follows:

1. Physical Research Laboratory (PRL) has received "First prize" for best implementation of Official Language Policy of Government of India during 2021-22.
2. PRL hosted the meeting of the Town Official Language Implementation Committee (TOLIC), Ahmedabad on 28 July 2022.
3. As a part of Azadi Ka Amrit Mahotsav, Gujrat State Level Hindi Essay Competition was conducted on June 5, 2022 and winners were awarded on August 12, 2022.
4. Official Language Implementation Committee (OLIC) were held regularly in every quarter chaired by Director, PRL, Dr. Anil Bhardwaj, Chairman OLIC, PRL. PRL OLIC meetings: 1. 29-06-2022 2. 20-09-2022 3. 26-12-2022 4. 13-03-2023.
5. Six members from PRL participated in Second All India Official Language Conference in Surat, Gujarat on occasion of Hindi Diwas
6. Celebration of Hindi Month during September 16 to October 11, 2022. Events organized:

   a. On 16th September, 2022 Online Hindi Book Exhibition was organized.

   b. Hindi Typing competition was organized on 19th September, 2022.

   c. On 20th September, 2022 Sulekh competition was organized.

   d. On 23rd September,2022 Hindi Kavita Path competition was organized.

   e. Ashulekhan Competition was organized on 27th September, 2022.

   f. On 3rd October, 2022 the Varg paheli Competition and Noting/Drafting were organized.

   g. 07 October, 2022: On the occasion of World Space Week celebrations a popular lecture on the topic "Understanding Space Weather: An essential part of ensuring Sustainability on Earth" was organized.

   h. 07 October, 2022: "Our Work" competition was conducted for Scientific and Administration Divisions.

   i. 08 October, 2022: Hindi Gayan program was held.

   j. 10 October, 2022: Word Quiz Competition was organized.

   k. 11 October, 2022: Laghunatika competition was organized.

7. Hindi Incentive Scheme for doing Original Work in Hindi 13 winners were awarded in this category.
8. Hindi workshops were organized in every quarter promoting implementation of Rajbhasha.
9. Participation of AD (OL) representing PRL in the following: (a) Official Language Orientation Program organized by Department of Space, Human Space Flight Center, Bengaluru on 22-24 June, 2022

   (b) "Kanthashtha Translation Tool Hindi Workshop" on 17 August, 2022 at ISRO HQ, Bengaluru

   (c) Invited as a faculty for Hindi Workshop on 18 August, 2022 at ISRO HQ, Bengaluru

10. On 12 August, 2022 Sushri Prachi Prajapati presented a Talk on "Importance of Hindi Language".
11. Monthly Online Hindi Book Exhibition with synopsis of general Hindi Books has been initiated by Rajbhasha Section on PRL Intranet from November, 2022.
12. The Departmental Inspection related to progressive use of Hindi of all campuses of PRL was conducted at different points of time as follows:

    i. On 21st December 2022, PRL Main Campus, Ahmedabad inspection was conducted by Controller, SDSC, SHAR

    ii. On 20th December 2022, PRL Mount Abu inspection was done by Controller, URSC

    iii. On 21st November 2022, USO inspection was conducted by Joint Director (O.L.) DOS

13. The wards of PRL Staff members, who have secured the highest marks in Hindi subject in CBSE/ICSE and State board in class XII and X board examinations of the year 2022, were given Merit Awards.
14. A ”Hindi Speech Competition” was organized on the occasion of World Hindi Day on 13th January 2023.
15. Participation of 10 PRL Members in Antakshri Competition organized by Space Applications Centre, Ahmedabad on 07 February, 2023.
16. Participation of 1 PRL member in Hindi Workshop organized by Western Railway, Sabarmati on 24 February, 2023.
17. Participation of 2 PRL members in Hindi Technical Seminar organized by NIOH on 15 March, 2023.
18. Participation of PRL members in Hindi Technical Seminar organized by Space Applications Center (SAC, ISRO) on 07 April 2022. 7 papers were presented by different members of PRL from various Scientific Divisions as per their research area.
19. Presentation and article by PRL members, in Bank TOLIC, Bank of Baroda on 18thJuly 2022.
20. On 3rd August 2022 in Audit Office, participation in Hindi Essay Competition by 2 Members.

Facilities and Services

Computer Networking and Information Technology (CNIT) Division

The Computer Networking & Information Technology Division (CNIT) is responsible for providing services/facilities like Networking (Internet, Local Area Network, Wifi, SPACENET), High performance Computing, E-mail, Web, DNS, Proxy, VPN, Centralized Printing, DHCP, Video Conference, EGPS, COWAA/COINS, software development and maintenance.

Apart from this, CNIT members have actively participated in ISRO/DOS level various Cyber Security Vulnerability Assessment & Penetration Testing (VAPT), Internal Cyber security Audit activities.

Following services/facilities are provided by CNIT team during the year 2022-2023.

[A] Participation in Hindi Language Promotion Activities:

Computer Networking & Information Technology Division has enthusiastically participated in PRL's Hindi Maah program of Laghunatika Pratiyogita of 2022-23. The CNIT team members have prepared a small Laghunatika/Skit on the theme of Cyber safety and security to spread the awareness regarding frauds happening in society for digital transactions. The CNIT Division won first prize in this competition for PRL's Laghunatika Pratiyogita of 2022-23. With the motivation, support and approval of Director, PRL, the CNIT team has participated in reels competitions organized by Gujarat Cyber Crime Cell and won the incentive (Protsahan) award.


State Cyber Crime Cell
CID Crime & Railways
Gujarat State, Gandhinagar

CERTIFICATE
OF APPRECIATION

We hereby present this certificate to

Team CNIT PRL

for your active participation in the online reels competition, for sharing your creative ideas and knowledge, and for helping people become aware of cybercrime.

R. B. Brahmbhatt, IPS
Additional Director General of Police,
CID Crime & Railways,
Gujarat State, Gandhinagar.

Date :13/09/2023

[B] Planning and Procurement of Upgradation to existing 100TF High Performance Computing (HPC) Cluster to 850TF HPC cluster at PRL:

The CNIT team along with HPC committee has successfully prepared new technical specifications, architecture and RFP for Upgradation of the existing 100TF cluster resources to $\sim$1000 TF HPC. To cater the high-end computing requirement of PRLs scientific & technical fraternity, the Request for Proposal (RFP) was prepared and was generic in nature which enabled participation of both open-source as well commercial solution provider. The installation of the $\sim$1000 TF HPC is under progress.

[C] Gateway level Multi-homing architecture using BGP in PRL

PRL has procured its own Internet Service Provider (ISP) independent IP Addresses. To enable them, we have procured Perimeter Network Security appliance with hardware level redundancy to implement Multi-homing architecture (using Border Gateway Protocol (BGP) which is a part of the TCP/IP protocol suite, to route between networks in a multi-homed network) In this regard CNIT has installed two Perimeter Security appliances in Main Campus CNIT Network room and implemented multi-homing, secure network access control mechanism, Threat detection Ruleset, High Availability & Failover mechanism for IPv4 and IPv6 public network addresses of PRL. The advantages of multi-homing architecture are:

1. Load balancing by dividing data across multiple ISPs.
2. Resilience to the network failures, better redundancy, and disaster recovery.
3. Improvement in the usage of all available network resources and performance, and bandwidth aggregation.
4. Simultaneous use of multiple network access. 5) Access of Internet with PRL's own IP address – No dependency on ISP IPs.

[D] National Science Day (NSD) 2023 and VIKAS scholarship student outreach activities:

PRL is celebrating National Science Day every year conduct various outreach activities. Since last year PRL has introduced VIKAS scholarship for the students in rural area. The selection in NSD and VIKAS is through registration followed by OMR based skill test. CNIT team members have developed application for registration and evaluating OMR sheets of student. There were more than 5000 students registered for NSD 2023 & VIKAS 2023 for which CNIT provided technical support for student registration and OMR evaluation. Total 5780 students from 3076 schools had participated in the OMR based examination of NSD & VIKAS scholarship of PRL. The examination went very well.

During NSD-2023, the PRL CNIT team has conducted on the spot online quiz based on general knowledge and basic science questions which was well appreciated by more than 120+ school students,

teachers, parents and staff members of PRL. The entire quiz software and setup was prepared using open-source tools and technologies by CNIT team.

[E] Cyber Security:

The team members also involved in various Cyber Security activities across DoS/ISRO which includes but not limited to, YUVIKA 2022, NRSC Bhuwan portal security audit, SACs UMANG integration, VAPT of INSPACe Web Application, New ISRO website, Cyber Security Mock Drill (CSMD) Level-6, Smart India Hackathon 2022, SAC recruitment application OSAR, various Root Cause Analysis and Breach analysis activities etc.

During the year 2022-2023, to protect PRL IT Infrastructure from cyber-attacks/threats, the Computer Networking & Information Technology Division members have taken suitable Cyber security measures based on the advisory received from Computer Emergency Response Team (CERT-In), National Critical Information Infrastructure Protection Centre (NCIIPC) and ISRO. The Information Security Officer (ISO) and CNIT team members also spreads cyber security awareness through online talk, allusers emails.

CNIT Division has completed Desktop and Laptop devices audit & re-registration to access the PRL network services for all staff members of PRL. Only after successful completion of Desktop/Laptop audit activities in compliance with PRL IT security policy the authorized devices were given access to PRL LAN resources. The CNIT has also enhanced the existing PRL WiFi registration software ("Tarang") to implement the changes suggested in PRL's New WiFi access policy.

[F] Management & Operationalization of key Services & Data Networks:

1. Email Server - PRL Email services runs smoothly entire year. All users was informed and sensitized about various email security threats like phishing, malware etc. via allusers email and internal talks. They were also given awareness about best practices for using secure email services
2. CCTV - CCTV surveillance Services having 150 CCTVs spread over various locations in PRL works smoothly entire year. Footage was successfully available whenever required for reviewing incidences, mock drills etc.
3. Student and PDF Hostel - Fast and reliable Wifi connectivity available in the Student and PDF blocks helped students and PDFs to access the PRL IT services and resources from their stay places to do their scientific work in outside office hours and non-working days also.
4. Dispensary - LAN connectivity to dispensary helped PRL medical officers to use centralized CHSS software to generate computerized prescriptions to the patients.
5. Live Streaming of PRL Events to Internet or LAN Network. - The CNIT team members along with live streaming committee have successfully coordinated and managed live streaming of various major events like Independence Day Celebrations, Republic Day Celebrations, and various Scientific Conference and events live transmission on PRL's YouTube channel.
6. Upgradation of PRL's VMware software suits To mitigate the recently announced vulnerabilities and threats on PRL's server virtualizations hosting architecture, CNIT periodically upgrades PRL's VMware Replication software, Site Recovery manager (SRM) and core software components like VMware vSphere and vCentre Server to latest stable version in both PRL's primary (DC) Server Virtualization site and Disaster Recovery (DR) site by preserving all running services and virtual machines data.

[G] Software Development and Management:

1. Endpoint Cyber Security Audit Application: In order to comply with the order no. DO.No.7(1)/2022-CSD dated 18.10.2022 circulated by MeitY, Government of India, ISRO/DOS order no. DISM/243/2022, dated 31/10/2022 and OCISO/71/2022, dated 24/12/2022, CNIT, has developed a Java based utility to automate the endpoints cyber security audit for OS and other installed software. This utility fetches required system information and automatically store to central database. A Dashboard has designed to access & view over all summary as well as detail MIS reports.

2. Recruitment Software: The CNIT team developed application to evaluate OMR based answer sheets of examination for the permanent post of Light Vehicle Driver. They were also team members to develop the recruitment application of permanent staff (Assistant and Junior Personal Assistant) which includes payment gateway integration and third-party security audit by CERT-In empaneled cyber security auditor.

3. Attendance Monitoring and Alert System (AMAS): AMAS system helps employees to remind his absence status from office on monthly basis. It generates notices to all employees who had not attended the defined office working hours. It has provision to submit employee response & their divisional hierarchy approval system.

Apart of these CNIT members are developing and managing various software like CoWAA/COINS, EGPS, BACS, PRL Website, Pension portal, Sandesh, Intranet Web Services, CHSS software, CLAP, ePPO, Canteen management software etc. PRL has also enrolled for SMS gateway which will be integrated with the PRL's upcoming recruitment of temporary/permanent posts.

[H] Vikram-100 High Performance Computing Cluster:

Vikram-100 100TF High Performance Computing (HPC) facility is extensively used by PRL Scientific & Technical fraternity. During April 01, 2022 to March 31, 2023 period 30 Scientific Papers have been published in reputed Scientific Journals where Vikram100 facility has been acknowledged. In total, 170 Scientific Papers have been published since June 2015.

Library & Information Services

Library and Information Services plays an important role in catering to the information needs of the PRL researchers and staff members. These information services are being provided on all the campuses of PRL. A few important ones are - documents (books, journals, CDs), lending services, Online Access (intranet and through remote access) to Institutional Repository, E-journals, Theses, E-books, Archives, Technical Reports etc. The library also provides the Inter library loan facility, specialized research support services of Similarity Check - iThenticate and Grammar Check Grammarly, a Reprographic facility, Information display through the Digital Notice Board and Book procurement for research scholars using their academic allowance. The updates and additions to the library during the year 2022-23 are mentioned below :

Statistics

In the year 2022-23, 193 Scientific, 24 General and 118 Hindi books were added to the collections of three libraries in Main, Thaltej and USO campuses. 1376 documents were issued, and the users returned 1623 documents to the library. PRL fulfilled 45 ILL requests, and 17 articles were sought from other institutes. The reprographic service of the library is in high demand, where the library facilitated 18966 photocopies in-house along with 9320 photocopies from an outside agency. 558 e-books and 209 Journals are available in the library, out of which 25 are printed and the rest online.

Library Online Resources

PRL Library continues to have access to full-text databases like GSA Archive, PROLA, Science Archive, Proquest Dissertation and Theses (PQDT). The Library has access to Nature.com and Springer Journals, Elsevier Journals and Wiley Journals in addition to SPIE and IEEE Digital Library through Antakriksh Gyaan, which is an ISRO Library Consortium. Librarys new website continues to provide a seamless facility of online resources and information to the library's patrons.

Plagiarism Check Facility

To create awareness about the prevention of research misconduct (Plagiarism) and promotion of academic integrity of the PRL community while conducting research, project work, assignment, thesis, dissertation, etc. PRL Library provides Similarity Check Service Using iThenticate software.

Digital Notice Board

The PRL Library uses Digital Notice Boards (DNBs) to disseminate information related to recent activities of the Library and PRL to the staff members and visitors. These are installed at prominent locations in the Main, Thaltej and USO Campuses. Information on recent publications of PRL scientists, new books added to the library collection, announcements of conferences, division seminars, colloquia, public talks, images of events etc., is being displayed.

Institutional Repository

The Institutional repository maintained by the Library consists of journal articles published by the PRL authors from 1990 and is also linked through the Library homepage. All the PRL theses from 1952 onwards (469) are now available in full text for PRL users. All the Technical Notes since 1977, published by PRL, have been digitized (117) and are available in full text for PRL users. Currently, the Library is carrying out the digitization of the photographs archive. Giving the captions and metadata for each photograph for easy retrieval is in the process using the digital library software Greenstone Digital Library (GSDL).

Book exhibition under the aegis of Azadi ka Amrut Mahotsav

The Library organized a book exhibition as a part of the AKAM activity at the Old Building Foyer, Thaltej Campus, on 26-27 January 2023. Around 600 scientific, general, and Hindi books were on display by three booksellers. The in-campus exhibition helps the staff browse many books in their area of interest, which are a useful addition to the library collection. The exhibition attracted active participation from research scholars, staff, and faculty members of PRL. There were 194 books recommended by them for the library and 4 books for personal use. The event was well received by research scholars, staff, and faculty members of PRL.

Figure no. 1 & 2: Glimpses of Books Exhibition.

Workshop

PRL's mechanical workshop has been actively working with various groups in the PRL. The workshop is engaged in the design optimization, fabrication, and testing of various mechanical subsystems of several ongoing development projects in the laboratory. The PRL workshop facilities in Navrangpura and Thaltej campuses are equipped with several state-of-the-art machines for the manufacturing of mechanical components, e.g. Vertical Machining Centre (VMC 850 & VMC 640), Wire Cut Electrical Discharge machine, Electrical Discharge Machine (EDM), CNC turning center (DX 200), Turn Mill Center (nvu 200), etc. In the financial year 2022-2023, the workshop has made notable contributions to the development of back-end instruments of Mt. Abu observatory as well as the development of various subsystems and setups for a number of scientific payloads for upcoming missions.

In addition, the workshop continues to cater to a number of specific requirements of several R&D laboratories in PRL by closely working with the members of the different Projects/Groups to develop specialized experimental setups. The workshop also continues to support various operational activities of laboratories and facilities in PRL. Highlights of some of the projects undertaken by the workshop during the financial year 2022-23 are briefly presented in subsequent sections.

Development of Multiwavelength Imaging Spectrograph Using Echelle Grating (MISE)

MISE (Multiwavelength Imaging Spectrograph using Echelle Grating) is a high spectral resolution with a large field-of-view (FOV; 140 degrees) instrument that is capable of retrieving faint dayglow emissions at Multiwavelength (OI 557.7, 630.0, and 777.4 nm) that are buried in the strong solar scattered background continuum.

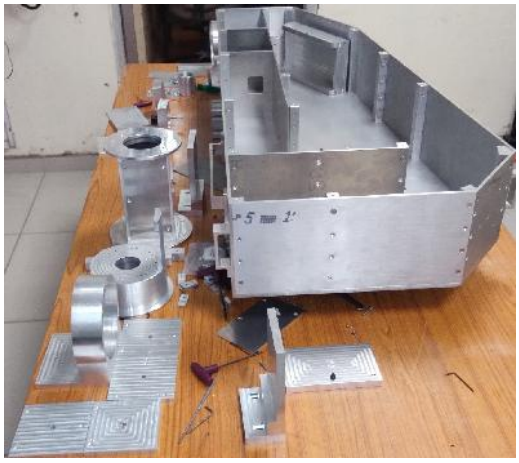

Figure no. 1: Multiwavelength Imaging Spectrograph Using Echelle Grating (MISE)

The Design of the "MISE" instrument for a Lens of 1200 & 1150 mm focal length was completed in PRL-Workshop during Year-2021, and a total of 118 nos. of parts for the "MISE" assembly, were fabricated in PRL-Workshop, main campus, mostly machined on VMC-850 m/c., during Year-2022. The overall dimensions of the MISE instrument are 1180 mm L x 500 mm W x 500 mm H. The Aluminium Profile Structure for the mounting of the "MISE" assembly at Gurushikhar, was designed & developed according to the Room & Dome dimensions (Mt. Abu). The mechanism for the 360° rotation of the "MISE" assembly was fabricated and assembled on the top surface of the Aluminium Profile Structure. Total of 1 no. Al. plate was fixed on the top surface of Al. profile structure in which a Thrust bearing was fitted and a Hub was fitted with a Top rotating plate, inserted through the thrust bearing which allows the 360 rotation of the top plate.

The installation & commissioning of the "MISE" Assembly at Gurushikhar, Mt. Abu, were completed in the month of October-2022 and observations are still continuing. We are planning to fabricate more new MISE assemblies to be deployed in diff. geographical locations, in the future.

Log Periodic Dipole Antenna Antenna Specifications: Frequency Range: 100-600 MHz
Gain: 8-9 dBi
Beam width: 50-90 degree
VSWR $<$2
Return Loss $<$ -10 dBi

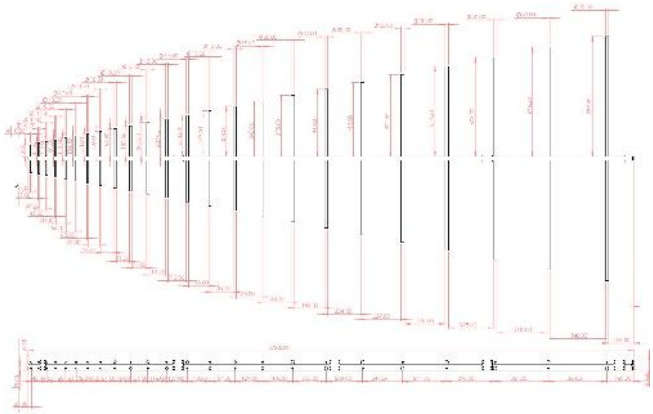

Figure no. 2: Log Periodic Dipole Antenna (LPDA-Details)

Design Parameters for Fabrication Number of Element = 24
Material for Boom and Elements = Aluminium 6063 grade
Length of Each Boom = 3.728 m (Parallel Two booms with spacing 13.6 mm)
Cross section = 25 mm 25 mm
Total Stub length = 3750 mm

The newly developed Log Periodic Dipole Antenna (LPDA) was designed, optimized, and fabricated indigenously at PRL-Workshop, main campus after being simulated in the CST software at the USO. The overall dimensions of the Antenna are 3750 mm x 1500 mm x 64.8 mm. The Antenna was being fabricated using a total of 65 nos. diff. components machined at PRL-Workshop, main campus as follows.

A. Aluminium Rods of Diff Sizes Qty.: 50 nos.
B. Aluminium Square Bar of Size 25 mm x 25 mm x 3750 mm Length-Qty.: 02 Nos.
C. Teflon Blocks of Diff. Sizes Qty.: 12 Nos.
D. Aluminium Block of Size: 58 mm x 25.4 mm x 64.8 mm

The extended Compound Astronomical Low-Cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (e-CALLISTO) is a worldwide network of radio spectrometers. It is used for the observation of solar radio bursts and radio frequency interference monitoring for astronomical sciences. An e-CALLISTO system is a valuable tool for monitoring solar activity and space weather research. The essential component of the front-end part consists of a Log Periodic Dipole Antenna (LPDA). The Udaipur-CALLISTO already had a facility to observe 45-250 MHz. The newly installed Log Periodic Dipole Antenna will observe at 100 - 600 MHz. Hence overall bandwidth to observe solar activity will increase, and therefore it is very useful to understand scientific processes on the sun.

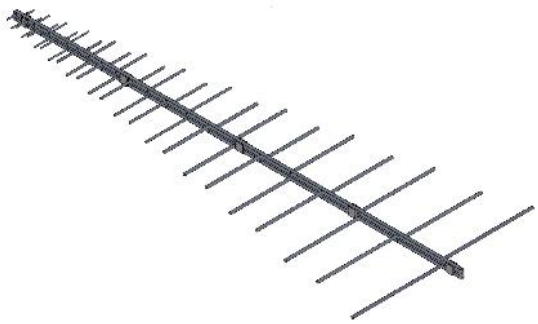

Figure no. 3: Log Periodic Dipole Antenna (LPDA-Model)

Low-Cost Inbuilt Shutter Assembly

Optical instruments measuring nighttime airglow emissions emanating from the upper atmosphere of the Earth requires mechanical, automated shutters to stop unwanted lights which are falling onto the sensitive detector in the presence of the moon. This shutter mechanism is designed and developed in-house and uses Arduino-Uno for controlling the motor mechanism. The mechanism is programmed in such a way that it allows the shutter to open only during moonless conditions.

Al. housing with both side threads of size 84 mm x 112 mm x 40 mm, 2 nos. of threaded brass lock rings, and a Shutter from Delrin material have been machined on the VMC machine. A provision for the assembling of the motor (servo Futaba 3003) to the Al. housing is kept, which coupled the shafting of the motor with the shutter. The geometry of the shutter is designed in such a way that fulfills the overall working of the Low-Cost Inbuilt Shutter Assembly.

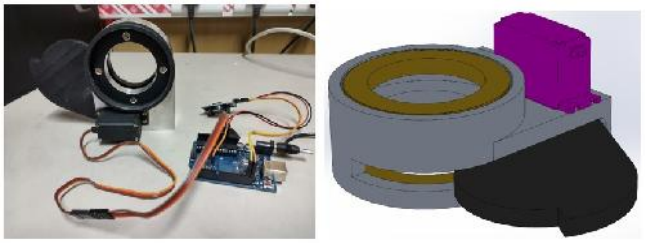

Figure no. 4: Low-Cost Inbuilt Shutter Assembly

Design and Fabrication of FEE (Front End Enclosure) and PE (Processing Electronics) Enclosures for LP

LP is a probe for studying the electron densities in situ and consists of two Sensors. The electronics developed have to be packaged in Aluminium enclosures. A total of 2 nos. of Aluminum packages were designed & developed and mounted over one other which minimizes the footprint of the package. The bottom enclosure houses two FEE PCB and the top enclosure houses the PE for both sensors. The top enclosure is attached to the bottom enclosure top plate (size: 286mm x 206mm x 5 mm) via screw joints. The overall size of the Bottom Al. enclosure is 286 mm L x 216 mm W x 85 mm H and the overall size of top Al. Enclosure is 226.5 mm x 177 mm x 75 mm. The D connectors for the PCBs are easily accessible from outside enabling a plug-and-play system for the package electronics. The machining of these 2 Al. enclosures & a top plate were being completed on the VMC-850 machine. Special long End-mill Cutters were used for the machining of these all parts.

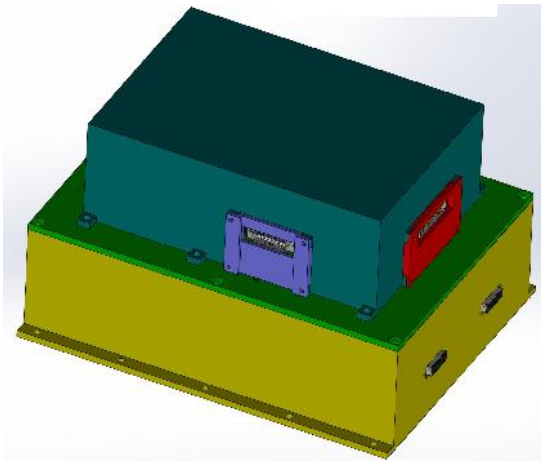

Figure no. 5: Design and Fabrication of Front End Enclosure and Processing Electronics Enclosures for LP

Design and Fabrication of NAVA for SCMOS Capella Sensors

NAVA is a photometer to measure airglow in the Venusian atmosphere both day and night time. It has a filter box and a barrel with the optics followed by an electronics box. The fabrication of the mechanical assembly for the SCMOS Capella sensor which is the detector finalized for NAVA was completed in PRL-Workshop, main campus. The assembly contains an electronic enclosure made of Al. which houses the FEE electronics detector chip and PE, lens barrels that house the lens element, and a temperature-controlled filter chamber containing the optical filter. A twin-barrel assembly was connected by a threaded joint and a lock ring which is a very unique concept of this assembly. This twin-barrel assembly enables easier focusing of optics manually, the pitch of threads is 1mm and thus the user can get very finer adjustments in Lens element to obtain sharp focus. The precision and accuracy were taken care of while the machining of a total of 16 nos. of parts of this assembly VMC-850 m/c.

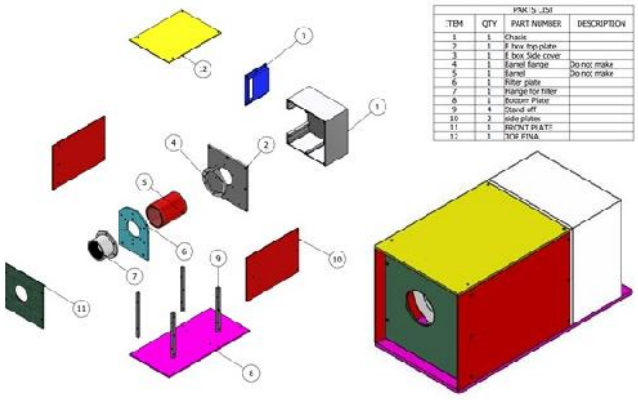

Figure no. 6: Design and Fabrication of NAVA for SCMOS Capella Sensors

Experimental Simulation of Lightning and Development of Lightning Detection Antenna for Future Planetary Missions.

The Vacuum Chamber of Size 3 feet L x 3 feet L x 3 feet L was designed and fabricated in PRL-Workshop, main campus. A 3-D CAD model was developed from the conceptual drawing and based on that the actual Vacuum Chamber was fabricated. The vacuum chamber will be filled up with various gases in similar proportions to simulate the Venusian environment or Earth Environment, and the facility of a Gas manifold system shall be set up which is useful for simulating a Venus-like environment. The facility is to be utilized for observation of the discharge through a CCD camera, and the event shall be recorded through the PC interface. The electrodes shall be fitted within the chamber, and the transparent holes are rendered by means of glass windows so that electrodes remain visible. Thus, with the help of this experiment, the User can experimentally simulate lightning discharge similar to Venus/Earth-like environment.

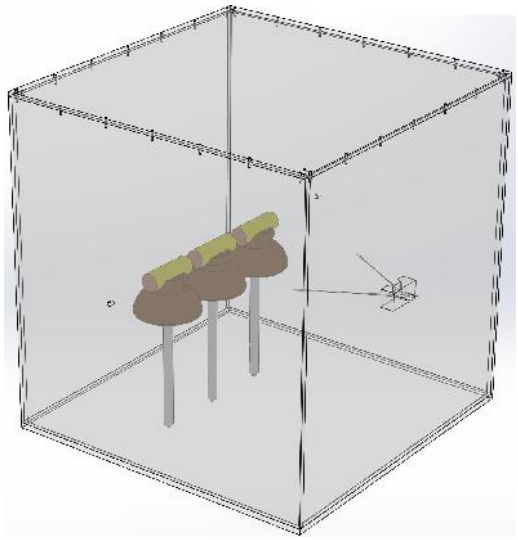

Figure no. 7: Experimental Simulation of Lightning and Development of Lightning Detection Antenna for Future Planetary Missions

A total of 3 nos. of Antennas (100 mm, 150 mm, & 250 mm) and Special Acrylic Fixture Blocks of diff. sizes had been designed and fabricated. The special Acrylic blocks have been designed such that the angle between the 2 antennas is maintained at 60 degrees after assembling in the Acrylic Blocks. The 3 size Caster wheels of good quality are fitted at the bottom Plate of the Vacuum Chamber for easy handling of the chamber.

Technical Details: The specifications required for Chamber are given below:
Material: Non-conducting (Acrylic)
Dimension of chamber: 3 feet x 3 feet x 3 feet
Antenna length: 10 cm/15 cm/25 cm
Distance between two electrodes: 10 cm
Number of ports required: 4

Trolley Structure with Copper Antenna for Lighting Experiment

The MS Trolley with Copper Antenna is being designed and fabricated to take the lighting measurement during the monsoon season.

The Technical requirements:

Trolley Base Material: MS
Trolley Covered By: Non-Conducting Material (Acrylic/Perspex)
Antenna Length: 1500mm
Antenna Angle: 120°
Antenna Material: Copper

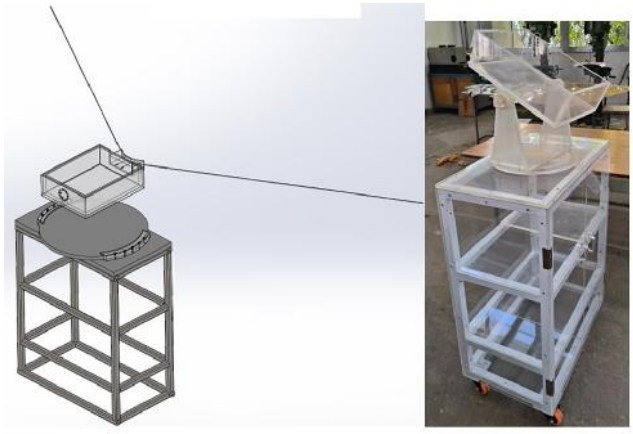

Figure no. 8: Trolley Structure with Copper Antenna for Lighting Experiment

The MS Trolley Structure is fabricated to mount the Acrylic Box on the top with Copper Antenna. The Size of the Trolley is 700 L mm x 400 W mm x 800 mm H and the Size of the Acrylic Box is 300 mm L x 250 mm W x 100 mm H. The MS Trolley is covered by an Acrylic Sheet (all around) of 3 mm thickness and at the Top, the Acrylic Plate of 20 mm thickness is fitted. Another Round plate is mounted on the bearing which allows 360° of rotation. For getting Elevatory movement, On the Top of the Rotating Acrylic Plate, 2 nos. of triangular supports are assembled which are to be used to fit an Acrylic Box by the Square Rod. This all items are indigenously designed and developed in PRL-Workshop, main campus. A special type of 2 nos. of Copper

Antennas fabricated from the Copper Rod of Dia. 4 mm x 1500 mm L. The angle of 120° between 2 nos. of Antennas was maintained by developing a special type of Acrylic fixture which is placed with the Acrylic box.

A total of 4 nos. of Dia. 2.5" caster wheels are placed at the bottom of the Trolley for the smooth movement of the whole Assembly.

Aerosol Sampling System

Figure no. 9: Aerosol Sampling System

ProtoPol: The Prototype Spectro-Polarimeter for PRL Telescopes

ProtoPol can be used on the existing 1.2m PRL telescope as well as on the upcoming 2.5m PRL telescope with suitable mechanical interfaces. It has been designed with off-the-shelf optical and mechanical components, making the design cost-effective and helping in quick instrument build-up. The use of off-the-shelf components helped immensely in the rapid development of this instrument. ProtoPol will provide the capability for low-resolution Spectro-Polarimetry of a variety of astrophysical objects.

The mechanical system of ProtoPol is designed and developed in a modular way for ease in the assembly-integration-testing process and for ease in transportation. It consists of three major modules and their sub-assemblies namely the Polarimeter unit, the Spectrometer unit, and the Calibration unit. In the instrument, the light from the telescope first enters the Polarimeter unit which consists of a set of 5 lenses, and 3 mirrors in addition to a few more specialized optical components (such as Wollaston prism and half-wave plate). Here the lenses are rigidly kept in place with custom-designed mechanical holders. This unit also contains a linear motorized stage for calibration optics, a motorized rotation stage (with a 1:70 reduction ratio) for a half-wave plate, and a small linear stage for a filter unit. The last mirror of this unit directs light into the spectrometer unit section.

In the spectrometer unit, the light beam is first collimated by a parabolic collimator mirror, which is then dispersed by an echelle and other cross-dispersers grating. All these components are mounted on a custom-designed mounting platform equipped with tip-tilt alignment stages with mechanical locking provisions, after the alignment of the instrument. Two cross-dispersers gratings are used which are mounted on two motorized linear stages equipped with guide rails. Finally, the light from the cross-disperser grating is directed into the Camera unit which is equipped with an off-the-shelf Canon camera lens system and ANDOR CCD detector system to finally record the data.

A calibration unit sits beside the Polarimeter unit and provides a calibration light beam for the spectral calibration of an instrument. The calibration unit has provision to mount 3 spectral lamps. There is also a provision of an Auto guider unit at the top interface of the instrument.

All the mounts for lenses, mirrors, gratings, linear stages, motors, etc. are developed in the PRL-Workshops with Aluminium alloy AA6061 T6 and are black anodized. The instrument is coupled to a 1.2 m and 2.5 m telescope using two different mounting systems and interfaces. These interfaces are made from SS-304 material. The figures show various views of the instrument at the assembly and subassembly levels.

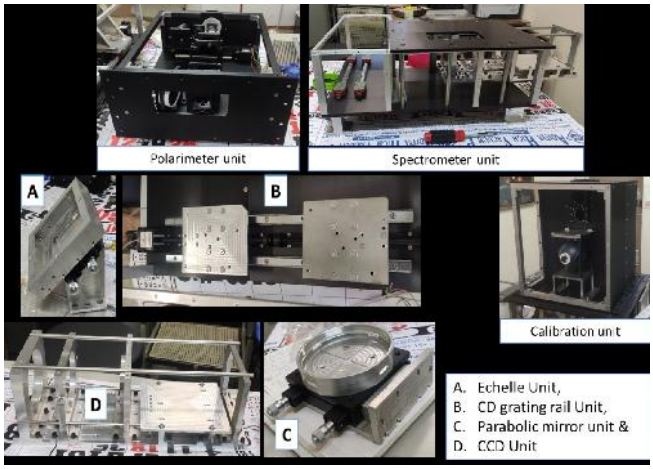

Figure no. 10: Various Images of Fabricated Subassemblies for PROTOPOL Instrument

Low-Resolution Spectrograph and Lens, Prism, & Mirror Assembly for PARAS-2 Cassegrain

A Total of 62 nos. of parts were fabricated for the assembly of a Low-Resolution Spectrograph (LRS) which is a back-end instrument for a 2.5m telescope. The instrument will be attached to side-port-2 of the telescope. It is designed & developed indigenously in-house at PRL-Workshop, main campus. As the name suggests, it will be used to carry out spectroscopy of various astronomical objects at low resolution. A dedicated Aluminum enclosure has been developed for the instrument, which houses the optical elements of the instrument. Necessary tolerances have been maintained to achieve the required performances of the instrument. The main interface flange SS-304 has been fabricated to attach the instrument to the telescope. A required SS counterweight has also been added for balancing purposes. Enough care has been taken to improve the aesthetics of the instrument.

Holders for lenses, prism, and mirrors have been designed and fabricated for PARAS-2 Cassegrain at PRL. The guiding rail has

been kept at the base to adjust the focus of the image. Necessary mechanical tolerances have been maintained to achieve the best focus.

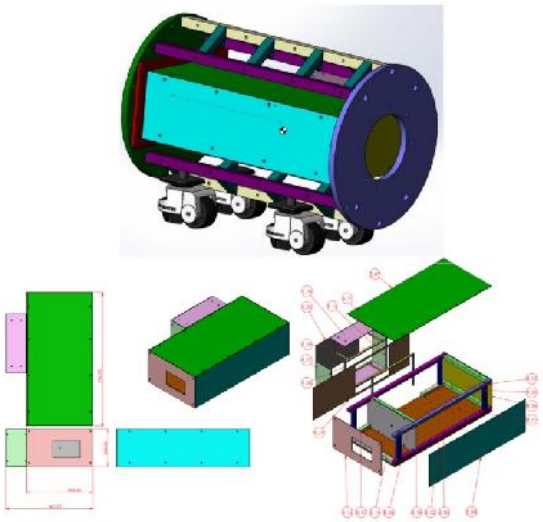

Figure no. 11: Low-Resolution Spectrograph for PARAS-2 Cassegrain

Activities Related to the Mt. Abu Observatory A. Atmospheric Dispersion Corrector (ADC) assembly for PARAS-2 instrument

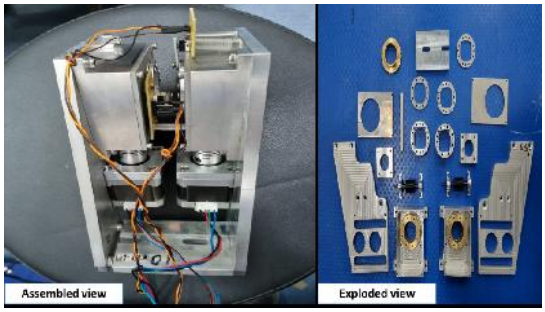

Figure no. 12: Atmospheric Dispersion Corrector(ADC) Assembly for PARAS-2

ADC is used to reduce the effect of aberration caused by the atmosphere. The assembly has two Prism rotating in opposite directions. A worm drive gear mechanism has been fabricated for each rotating prism. This assembly requires to be fabricated with high precision and accuracy. The gears and their assembly need a high accuracy level in fabrication. The assembly was fabricated using the CAM programming on the VMC-640 machine tool at the Thaltej workshop facility. The fabrication utilized wire-cut EDM also.

B. Neutral Density filter assembly for 2.5 m telescope

A new Neutral Density filter assembly has been fabricated at the PRL Thaltej workshop facility for the Faint Object Camera (FOC) of the 2.5m telescope. A neutral Density filter is used to reduce the amount of light entering the detector. The machine tools used were CNC turning center DX-200, VMC-640, and EDM wire cut. The rack & pinion mating surfaces were made with controlled tolerances and surface finish to end up in excellent fitting. The positioning accuracy of the assembly was maintained as per drawing specifications.

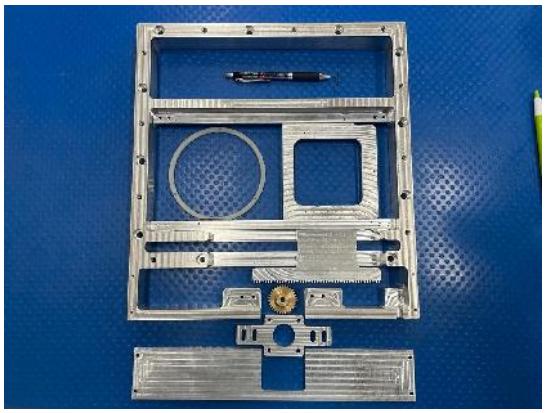

Figure no.: 13 Workshopfig 13 A Glimpse of the Fabricated Components of ND Filter Assembly

Activities related to the Development of Payloads for Future Missions
A. ChaSTE Probe prototype for lab characterization

ChaSTE is a payload onboard Lander in the Chadrayaan-3 payload. For performing the characterization tests in the lab, the lab model needed to be fabricated using Aluminium and Teflon material. The laboratory model was fabricated at the Thaltej workshop. The metallic tip was made in a close fit with the cylindrical structure of the probe. The Teflon material base cylindrical structure was fabricated with precision turning while taking care of lateral deflection. The assembled probe is shown in the figure.

B ASPEX payload flight hardware: Gas Purging Containers

The detectors in the ASPEX payload are needed to be kept in a controlled environment. For that purpose, a set of purging containers were fabricated in the Thaltej workshop facility. These containers were machined from single solid raw materials so as to minimize the number of leakage interfaces. The containers involved machining on a VMC-640 machine with different settings and machining processes and involving special holding and fixtures. Also, many moulds were fabricated for the casting of customized seals for vacuum applications in the various stages of testing/calibration of the payload.

C Magnetic Lock Rings for ASPEX Payload Calibration Activities

For the calibration of the ASPEX payload, the source uses various Magnetic lock rings. These rings with precisely located slots were fabricated with the use of CAM programming in the VMC-640 machine at the Thaltej workshop. The rings were of outer diameter of 99 mm and a thickness of 3.2 mm. The rings were used successfully in the testing application as per the user's feedback.

D FEE enclosure for DAKSHA mission

For the payload development activities in connection with the future DAKSHA mission, front end electronics enclosure with a customized design was fabricated at the Thaltej workshop. This involved precision machining with CAM programming and utilization of the VMC-640 and wire-cut EDM machine tools of the Thaltej workshop.

Figure no. 14: ChaSTE Probe Lab Model

Other Developmental Activities for Various Divisions A. Two-axis Manipulator for SIMPEX Lab

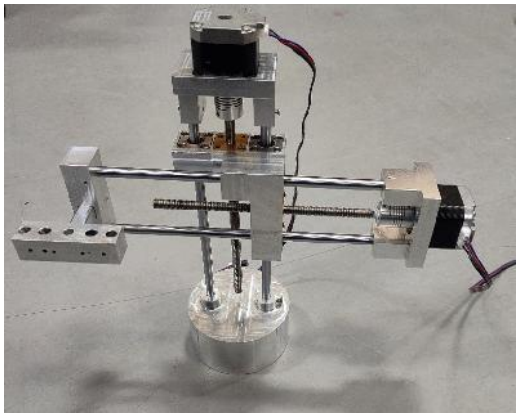

Figure no. 15: Assembled View of the 2-Axis Manipulator

Two-axis manipulator is used inside the vacuum chamber with a simulated space environment in the SIMPEX lab of the planetary sciences division. The manipulator with precision components is fabricated at the Thaltej workshop facility. The manipulator is used to control the movement of the reflectance probe of a reflectance spectrometer, thus operating it remotely. 2 axis motion of spectrometer probes is achieved through a stepper motor and screw-nut movement. In each axis set of linear guides, rods are provided. The assembly of the manipulator is dimensionally controlled and caters to great accuracy with very low operational disturbances to the probe.

B. X-ray optics development: mandrel for depositing a thin film

For developing a customized thin film for focusing the X-rays, there was a need of developing mandrels of various sizes with a very grazing angle and high level of surface finish. A set of mandrels with dimensional accuracy and excellent surface finish were fabricated at the Thaltej workshop utilizing the DX-200 CNC turning center.

Figure no.: 16 Workshopfig19 Mandrel for Thin Film Deposition for X-Ray Optics Development

C. OSL Sampling Tube Production

In the geological sample collection, these sampling tubes are used. The sampling tube assembly consists of a metallic tube with a sharp-edged tip for sample collection at one end. On the other end, it has a fixed end cap which is press fitted to the tube body. The sealing cap is fixed on the tube after sample collection and this cap is fitted using an O-ring. For handling ease, it is provided with knurling. This work involves precise fitting of each part with respect to each other, hence precision turning is done on a CNC lathe machine. The materials used are Aluminium and Steel. The Thaltej workshop produced a large batch of sampling tubes for meeting the user requirements.

Figure no.: 17 Workshopfig20 OSL Sampling Tube Sets

D. Development of Website for the “Thaltej Workshop Facility”

For the first time the ‘Thaltej workshop facility’ developed its website which gives information on the functioning of the facility, products

Figure no.: 18 Workshopfig21 Home Page of Thaltej Workshop Facility webpage (with QR code to Scan)

range, machining tools capability of the facility, etc. The development work was led by the In-charge of the facility with the active involvement of the team members and support of the CNIT division in web hosting. A few screenshots of the website are presented in this section. For more details kindly visit `https://www.prl.res.in/~thaltejws/` by scanning the QR code embedded in the following figure.

Honorary Fellow & Faculties

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K. Kasturirangan

Honorary Faculty

A. K. Singhvi
FNA, FASc, FNASc, FTWAS
DST Year of Science Chair Professor

DPK Banerjee
CSIR Emeritus Scientist

J. N. Goswami
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INSA Senior Scientist

S. A. Haider
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M. M. Sarin
FNA, FASc, FNASc
DST-SERB-Distinguished Fellowship.

Shyam Lal
FNA, FASc, FNASc
INSA Senior Scientist

S.D. Rindani
FNASc & INSA Senior Scientist

P. Janardhan
FNA, INSA Senior Scientist

PRL Staff

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3	A. Shivam	Sci./Eng.-SD	Electronics Development and Accelerator Mass Spectrometry	GSDN	M.Tech. (2018)
4	Aaditya Sarda	Sci./Eng.-SD	Design And Development Of Space Based Instruments	SPASC	B.Tech. (2015)
5	Abhijit Chakraborty Head, A&A	Senior Professor	Astronomy, Exoplanets, Optical Instrumentation, Stellar High Resolution Spectroscopy	A&A	PhD (1999)
6	Abhishek	Admin. Officer	General Administration	USO	PGDip. (2009)
7	Abhishek J. Verma	Sci./Eng.-SD	Mechanical design and analysis of payload systems, Lab. reflectance spectroscopy, UHV Vacuum experimets	PSDN	B.E. (2016)
8	Abhishek Kumar	Sci./Eng.-SC	Optical Engineering	SPASC	M.Tech.(Integrated) (2022)
9	Abhishek Prasad	Assistant	Administration	ADMGN	B.Sc. (2013)
10	Adalja Hiteshkumar Lavjibhai	Sci./Eng.-SE	Mechanical Engineering	A&A	M.Tech. (2009)
11	Akash Ganguly	Sci./Eng.-SD	Machine Learning Applications In Groundwater/Climate Change, Numerical Modelling and Instrumentation	GSDN	B.E. (2017)
12	Alka	Sci./Eng.-SD	Hardware and Software Design development, Embedded Systems, Ground Based Instrumentation.	A&A	B.E. (2015)
13	Alok Shrivastava	Sci./Eng.-SD	Cyber Security, System Administration, Networking	CNIT	M.Sc. (1998)
14	Aman K Khatri	Sci./Eng.-SC	Civil Engineering	CMDV	B.E. (2017)
15	Amee Kartikkumar Patel	Sr. Proj. Assistant	Purchase And Accounts Work	ADMAC	M.B.A. (2011)
16	Amit Basu Sarbadhikari	Asso. Professor	Planetary Geochemistry	PSDN	PhD (2007)
17	Amitava Guharay	Asso. Professor	Atmospheric Waves, Middle Atmospheric Dynamics, Dynamical Coupling In Atmosphere	SPASC	PhD (2010)
18	Amzad Hussain Laskar	Asst. Professor	Paleoclimate, Isotope Hydrology, Non-Traditional Stable Isotope Geochemistry, Geochronology	GSDN	PhD (2012)
19	Anand Dinesh Mehta	Head P & G A	Personnel And General Administration, Establishment, Recruitmant and Legal Matters	ADMGN	M.B.A. (2012)
20	Aniket	Sci./Eng.-SC	Aerospace Engineering	SPASC	B.Tech. (2022)
21	Anil Bhardwaj FNA, FASc, FNASc	Director & Distinguished Professor	Planetary And Space Sciences, Solar System Exploration	ADMDIR	PhD (1992)
22	Anilkumar Lakshmishankar Yadav	Sr. Sci. Assistant-A	Optical Instrumentation For Airglow And GPS/GNSS/IRNSS For TEC Measurments	SPASC	M.Sc. (2014)
23	Anirban Ghosh	Sr. Sci. Assistant-A	Semiconductor Device, Photonics, Nonlinear Optics, Quantum Optics, Structured Optical Beams	AMOPH	M.Sc. (2016)
24	Anisha Kulhari	Sr. Sci. Assistant-A	Scientific Observations	USO	M.Sc. (2016)
25	Ankala Raja Bayanna	Sci./Eng.-SF	Optical Instrumentation, Adaptive Optics, Solar Physics	USO	PhD (2015)
26	Ankita Patel	Sci./Eng.-SD	Electronic Instrument Control System, GUI, PCB Designing and Firmware Development, PC Based Real Time Control System For AO, Mechanical 3D CAD Modelling	A&A	B.E. (2015)
27	Ankurkumar J Dabhi	Sr. Sci. Assistant-A	Condensed Matter Physics, Graphitisation, Accelerator Mass Spectrometer, Radiocarbon Dating, Isotope-Ratio Mass Spectrometery	GSDN	M.Sc. (2016)

Sr. No.	Name	Designation	Specialization	Division	Highest Degree Obtained
28	Arpit Rasiklal Patel	Sci./Eng.-SE	FPGA based signal systems design, Scientific Instruments Hardware & Software Design And Development For Space Missions	PSDN	M.E. (2010)
29	Arvind Singh	Asso. Professor	Ocean Biogeochemistry And Climate Change	GSDN	PhD (2011)
30	Arvind Singh Rajpurohit	Asst. Professor	Atmosphere Of Very Low Mass Stars And Brown Dwarfs	A&A	PhD (2013)
31	Aseem Jaini	Sci./Eng.-SD	Civil Engineering	CMDV	B.Tech. (2016)
32	Ashirbad Nayak	Sci./Eng.-SD	Electronics	A&A	B.E. (2017)
33	Ashish Govindrao Sawadkar	Senior Assistant	Hindi section and administration related work	ADMGN	CC (2006)
34	Ashish Kumar	Sci./Eng.-SC	Civil Engineering	USO	B.Tech. (2016)
35	Atul Ashok Manke	Sci./Eng.-SD	Software development and scientific data analysis	SPASC	M.Tech. (2013)
36	Avadh Kumar	Sci. Assistant	Noble Gase Mass spectrometery and Vacuum Setups	PSDN	M.Sc. (2018)
37	Aveek Sarkar	Asso. Professor	Magnetohydrodynamic Simulation	A&A	PhD (2005)
38	B G Thakor	Sr. Proj. Attendant	Purchase attendent	ADMPR	Ninth (1991)
39	B. S. Bharath Saiguhan	Sci./Eng.-SC	Astronomy & Astrophysics	A&A	MS (Integrated) (2021)
40	B. Anne Matilda	Admin. Officer	General Administration and Accounts	ADMGN	M.Com (1997)
41	Bankimchandra N Pandya	Technician-G	Scientific Glass Blowing	GSDN	I.T.I (2003)
42	Bhalamurugan Sivaraman	Asso. Professor	Astrochemistry - Astrobiology	AMOPH	PhD (2009)
43	Bhupendra J Panchal	Sr.Tech.-A	Plumbing services	CMDV	M.A. (2002)
44	Bhushit Girishbhai Vaishnav	Sci./Eng.-SE	Theoretical Atomic And Molecular Physics, Academic Administration, Scientific Editing And Reports Preparation	ADMDN	PhD (2008)
45	Bhuwan Joshi Dy. Head-I, USO	Professor	Solar Physics	USO	PhD (2007)
46	Bijaya Kumar Sahoo Dy. Head-II, AMOPH	Professor	Probing Sub-Atomic Physics, Relativistic Atomic And Molecular Many-Body Methods, Computational Physics	AMOPH	PhD (2006)
47	Binal Pratik Umarwadia	Sr. Pharmacist-B	Pharmacy administration and PRL dispensary coordination	DISSR	D.P (1987)
48	Bireddy Ramya	Sci./Eng.-SE	Instrumentation, Programming, Telescope Operation,Circuit And PCB Design	USO	M.Tech. (2019)
49	Brajesh Kumar	Asso. Professor	Solar Physics, Solar Oscillations, Solar Energetic Transients, Solar Rotation, Solar Adaptive Optics	USO	PhD (2007)
50	Chandan Kumar	Sci./Eng.-SD	Payload Development, Scientific Instruments Hardware & Software Design And Development For Space Missions Data Anlaysis	PSDN	B.Tech. (2015)
51	Cherukuri Sree Vaishnava	Sci./Eng.-SC	High Energy Astrophysics And Instrumentation	A&A	M.Sc. (2019)
52	Chithra Raghavan	Sci./Eng.-SD	Space-Based Instrumentation And Simulations For Ionospheric Studies	SPASC	M.Tech. (2019)
53	D L Kalal	Project Cook	Project Cook	ADMGN	Ninth (1986)
54	D. Pallam Raju FASc	Dean & Sr. Professor	Space Weather, Magnetoshpere-Ionosphere-Thermosphere Coupling Processes, Ground And Space-Based Instrumentation	SPASC	PhD (1997)
55	Debabrata Banerjee Dy. Head-II, PSDN	Professor	Planetary Science, Gamma Ray Spectroscopy And Luminescence Physics	PSDN	PhD (1997)
56	Debi Prasad Pradhan	Senior Admin. Officer	General and CHSS administration	ADMGN	M.B.A. (2016)
57	Deekshya Roy Sarkar	Sci./Eng.-SD	Avionics Engineering, Hardware Design, Software Programming, Fpga Firmware Development, Ground Based Instrumentation	A&A	B.Tech. (2016)
58	Deepak Kumar Painkra	Sci./Eng.-SC	Electronics And Instrumentation	PSDN	B.Tech. (2018)
59	Deepak Kumar Prasad	Assistant	Accounts services	ADMAC	B.Sc. (2014)
60	Dibyendu Chakrabarty Head, SPASC	Professor	Space Weather, Ionosphere, Thermosphere, Magnetosphere, Solar Wind	SPASC	PhD (2008)

Sr. No.	Name	Designation	Specialization	Division	Highest Degree Obtained
61	Dinesh Mehta	Sci./Eng.-SE	Web Development, Database and System Administration, Cyber Security, IT Security Testing	ADMDN	M.Tech. (2013)
62	Dinesh Yadav	Sci. Assistant	Scientific Observations	A&A	M.Sc. (2018)
63	Dipak J Panchal	Senior Assistant	Account services	ADMAC	CC (2018)
64	Dipak Kumar Panda	Sci./Eng.-SF	Nuclear Instrumentation, Planetary Science, Meteorites, Geochemistry, Isotope Geochemistry	PSDN	PhD (2019)
65	Divyang G. Adyalkar	Senior Nurse-B	PRL Dispensary services	DISSR	D.N (2006)
66	Dwijesh Ray	Asso. Professor	Meteorites, Planetary Geology, Igneous Petrology, Geochemistry	PSDN	PhD (2009)
67	Femics George	Assistant	Accounts services	ADMAC	B.Com (2015)
68	G S Rajpurohit	Sr. Tech. Assistant-D	Scientific Observation	A&A	B.Sc. (1986)
69	Garima Arora	Sr. Sci. Assistant-A	Gurushikhar IR Observatory, Mount Abu	PSDN	M.Sc. (2015)
70	Girjesh R Gupta	Asst. Professor	Solar Physics	USO	PhD (2011)
71	Goutam Kumar Samanta Dy. Head-I, AMOPH	Professor	Quantum Optics, Stuctured Optical Beams, Photonics, Nonlinear Optics, Quantum Sensing, Quantum Communication	AMOPH	PhD (2009)
72	H R Vaghela Head, Workshop	Sci./Eng.-SF	Draughting, Designing,CAD/CAM, Programming And Operating/Handling Of CNC Machines	WORSH	M.B.A. (2003)
73	Harish Shivraj Gadhavi	Asso. Professor	Atmospheric Aerosols, Black Carbon, Remote Sensing, Climate Change, Data Analysis, Scientific Computing, Python, Fortran	SPASC	PhD (2006)
74	Harsh Chopra	Sr.Tech.-A	Assistance with PCB preparation and trouble shooting at USO	USO	CC (1990)
75	Harshaben Parmar	Sr. Proj. Assistant	General Administration, Clerical & Routine Office Work	ADMGN	M.B.A. (2011)
76	Hemal Deepakkumar Shah	Head P & S	Stores and Purchase administration	ADMPR	M.B.A. (2003)
77	Hiral Dhruvin Modi	Senior Assistant	Director's office administration	ADMDIR	CC (2016)
78	Hitendra Dutta Mishra	Sci./Eng.-SD	System Management, Networks And IT Security	CNIT	M.C.A (2003)
79	Hitesh Chandulal Panchal	Sr. Accounts Officer	Accounts services	ADMAC	M.Com (2012)
80	Ishita Pravinchandra Shah	Accounts Officer	Pre-Auditing, MIS Reporting, Budgeting and Accounting related services and Taxation	ADMAC	CA (2011)
81	J K Jain	Sr. Technical Assistant D	Scientific Observations	A&A	M.Sc (2009)
82	J. P. Pabari	Asso. Professor	Interplanetary Dust Science, Planetary Lightning, Remote Sensing, Space Instrumentation And Sensor Development, Wireless Communication And Signal/Image Processing	PSDN	PhD (2011)
83	Jacob Sebastian	Sci./Eng.-SC	Space & Atmospheric Sciences	SPASC	MTech (Integrated) (2021)
84	Jaldhi Tarunkumar Mehta	Senior Assistant	General Administration of Geosciences Division	GSDN	PGDBM (2012)
85	Janmejay Kumar	Sci./Eng.-SD	Mechanical Engineering, Payload Design, Solidworks, Ansys, Nx, And Comsol Softwares.	PSDN	B.Tech. (2015)
86	Jayanth R.	Sci./Eng.-SC	Atomic Molecular and Optical Physics	AMOPH	MTech (Integrated) (2021)
87	Jaya Krishna Meka	Sci./Eng.-SD	Electronics Engineer, CAD Designer, Instrumentation And FPGA Progrmming	AMOPH	B.Tech. (2015)
88	Jayashree Balan Iyer	Sr. Proj. Assistant	CHSS, BACS, Visitor Mgmnt System, Despatch, Pension Cards, Liasoning Work	ADMGN	B.HSc. (1993)
89	Jigarbhai A Raval Head, CNIT	Sci./Eng.-SF	Cyber Security, Linux System And Network Administration, High Performance Computing	CNIT	B.E. (1999)
90	Jitender Kumar	Sr. Sci. Assistant-A	Assistance with Mass spectrometric instruments	GSDN	M.Sc. (2015)
91	Jitendra Kumar Panchal	Technician-G	Electrical Maintenance	CMDV	I.T.I (2007)
92	Jyoti Limbat	Assistant	Registrar's office Administration	ADMRO	M.Sc. (2015)

Sr. No.	Name	Designation	Specialization	Division	Highest Degree Obtained
93	Jyotiranjan S. Ray	Sr. Professor	Isotope Geochemistry	GSDN	PhD (1998)
94	K J Bhavsar	Sci./Eng.-SE	Electrical work	CMDV	B.E. (1995)
95	K.K. Sasikumar	Sr. Admn. Officer	Transport, Estate And Right To Information	ADMGN	M.B.A. (2014)
96	Kaila Bipinkumar	Technician-G	Oparating & Programing On CNC/VMC And EDM Machines, CAD Modeling and CAM Programming	WORSH	TC (2007)
97	Kanhav Mulasi	Assistant	General Administration	ADMGN	B.Sc. (2017)
98	Kapil Kumar	Sci./Eng.-SD	Astronomical Spectrograph Design, Exoplanetary Science, Mechanical Structural Design, Optimization And Testing, Vacuum Chamber Design, Basic Optical And Optomechanical Design, Basic Astronomical Telescope And Coating Technology	A&A	B.Tech. (2015)
99	Karanam Durga Prasad	Sci./Eng.-SF	Lunar And Planetary Surface Science, Space Instrumentation, Simulation Of Planetary Environments, Numerical Modelling, Planetary Wireless Sensor Networks & Cubesats	PSDN	PhD (2018)
100	Kartik Patel	Admin. Officer	General Administration & Establishment	ADMGN	M.B.A. (2011)
101	Kasarla Prashanth Kumar	Sci./Eng.-SD	Mechanical System Design, Optical And Opto-Mechanical System Design, Dewar And Cryostat Design And Testing, Instrumentation	A&A	B.E. (2017)
102	Kavutarapu Venkatesh	Asst. Professor	Space and Atmospheric Sciences	SPASC	PhD(2013)
103	Keshav Prasad	Technical Assistant	Construction And Maintenance	CMG	B.Tech. (2018)
104	Ketan Patel	Assoicate. Professor	Theoretical High Energy Physics	THEPH	PhD (2012)
105	Keyur D Panchasara	Sr. Proj. Assistant	Cashier & Miscellaneous Payment Work	ADMAC	B.Com (2003)
106	Kinsuk Acharyya	Asso. Professor	Astrochemistry And Astrobiology	PSDN	PhD (2008)
107	Kolencheri Jithendran Nikitha	Sci./Eng.-SC	Astronomy and Astrophysics	A&A	MS (Integrated) (2021)
108	Kuljeet Kaur Marhas	Professor	Isotope Cosmochemistry, Planetary Scientist	PSDN	PhD (2001)
109	Kuntar Bhagirathkumar K	Administrative Officer	Administrative Work	ADMGN	CC (2018)
110	Kushagra Upadhyay	Sci./Eng.-SD	Antenna Design, RF System And Circuit Design, Solar Radio Instrumentation	USO	B.Tech. (2017)
111	Lad Kevikumar Ashokbhai	Sci./Eng.-SD	Instrumentation, CAD, Finite Element Analysis, Experimental And Computational Fluid Dynamics, Thin Film Coating Systems, Design And Optimization	A&A	B.E. (2017)
112	Lakhansinh G Chavda	Sr. Technician-A	Troubleshooting Of Electronics Breakdown In Scientific Instruments. Soldering/Desoldering work	GSDN	I.T.I (2006)
113	Lakum Yagnikkumar Bhimjibhai	Technician-F	Electronics and IT assistance	CNIT	COMPTR (2011)
114	Lokesh Kumar Dewangan	Asst. Professor	Star Formation	A&A	PhD (2011)
115	Lokesh Kumar Sahu	Professor Dy. Head-I, SPASC	Atmospheric Sciences,Trace Gases, Volatile Organic Compounds (VOCs)	SPASC	PhD (2005)
116	Lovjeet Meena	Technical Assistant.	Civil Engineer	USO	D.C.E (2013)
117	M G Yadava	Professor	Radiocarbon Dating And Paleoclimatology	GSDN	PhD (2003)
118	Mahesh Chand Saini	Technical Assistant.	Astronomy & Astrophysics	AST-AS	Dip. (2017)
119	Mahesh Gaddam	Sr. Sci. Assistant-A	Maintenance And Operation Of Various Instruments Present In The Chemistry Lab	GSDN	M.Sc. (2013)
120	Mahesh Kumar A Raval	Senior Lv Driver-B	Driver	ADMGN	Ninth (1989)
121	Malaidevan P	Sci./Eng.-SD	Electronics (Avionics), Solidwork Software	SPASC	B.Tech. (2015)
122	Manan Shah	Sci./Eng.-SE	Electronics, Design And Development Of Space And Ground Based Scientific Instruments	GSDN	M.Sc. (2016)
123	Manash Ranjan Samal	Associate Professor	Astronomy And Astrophysics: Star Formation, Star Clusters, Interstellar Medium, Young Stellar Objects	A&A	PhD (2011)
124	Manisha D Patel	Senior Nurse-B	Nursing	DISSR	B.Sc. (2009)
125	Manisha Mishra	Sr. Proj. Assistant	Assistance with Purchase and Procurement	ADMPR	M.Sc. (2011)
126	Mantu Meher	Assistant	Procurement (GeM, Coins, Cash Purchase)	ADMPR	B.Sc. (2015)

Sr. No.	Name	Designation	Specialization	Division	Highest Degree Obtained
127	Md. Nurul Alam	Library Assistant-B	Library Automation, Digital Library, Scientometrics, Digitization, Serials Control	LIBSR	PhD (2017)
128	Megha Upendra Bhatt	Assistant Professor	Planetary Remote Sensing, Visible - Infrared Spectroscopy	PSDN	PhD (2012)
129	Mistry Bhaveshkumar Vinodbhai	Technical Assistant	Astronomy & Astrophysics	AST-AS	B.E. (2021)
130	Mitesh B Bhavsar	Sr.Technician-A	Circuit Fabrication And Testing, Soldering/Desoldering Work, Supporting Space Science Instrumentation	SPASC	I.T.I (1998)
131	Mithun Neelakandan Ps	Sci./Eng.-SE	High Energy Astrophysics And Instrumentation	A&A	B.Tech. (2014)
132	Mohit Kumar Soni	Sci./Eng.-SC	Avionics Instrumentation (Hardware And Software), Ground Based Insturmentation, Image Processing And Deep Learning	SPASC	B.Tech. (2019)
133	Mudit Kumar Srivastava	Asso. Professor	Observational Astronomy, Studies Of Novae, Symbiotic Stars And Transients, Optical Astronomical Instrumentation, Design And Development Of Optical Imaging And Spectroscopy Instruments	A&A	PhD (2012)
134	N Jain	Sci./Eng.-SE	Design, Development And Coordinate Maintenance Of Electrical Systems at USO	USO	AMIE (2002)
135	N S Rajput	Sr.Tech.-A	Assitance with Telescope operations	A&A	Eight (1985)
136	Nafees Ahmad	Sci./Eng.-SC	Upgradation of 1.2M Infrared Telescope Upgradation, Operations And Maintenance.	A&A	AMIE (2015)
137	Namit Mahajan Dy. Head-I, THEPH	Professor	Theoretical High Energy Physics	THEPH	PhD (2004)
138	Nandini Ravi Rao	Pur. & Stores Officer	Purchase administration	ADMPR	B.Sc. (1991)
139	Nandita Srivastava	Sr. Professor	Solar Physics, Space Weather	USO	PhD (1994)
140	Narendra Ojha	Assistant Professor	Atmospheric Chemistry, Earth System Modeling	SPASC	PhD (2014)
141	Naveen Chauhan	Asst. Professor	Luminescence Dating, Luminescence Physics, Dosimetry	AMOPH	PhD (2013)
142	Navinder Singh	Professor	Theoretical Condensed Matter Physics	THEPH	PhD (2006)
143	Neelam J S S V Prasad	Sci./Eng.-SD	Ground Based Instrumentation, Design And Development Of Hardware And Software For Telescope Back-end Instruments And Control System For Scientific Detectors, Antenna Design And Basic Astronomical Telescope Technology	A&A	B.Tech. (2015)
144	Neeraj Kumar Tiwari	Sci./Eng.-SD	Mechanical And Thermal Design Of Space Instruments And X-Ray Optics Development	A&A	B.Tech. (2015)
145	Neeraj Rastogi Dy. Head-II, GSDN	Asso. Professor	Atmospheric Science: Aerosol Chemistry, Composition, And Characteristics	GSDN	PhD (2005)
146	Neeraj Srivastava	Asso. Professor	Planetary Remote Sensing: Mission Data Analysis For Geology & Laboratory Reflectance Spectroscopy Under Smulated Conditions	PSDN	PhD (2015)
147	Nileshkumar N Dodiya	Sr.Tech.-A	Carpentary Work	CMDV	CC (2000)
148	Nimma Vinitha	Sci./Eng.-SC	Ultrafast Spectroscopy, Laser Physics, Optical Instrumentation	AMOPH	M.Tech. (2019)
149	Nirbhay Kumar Upadhyay	Sci./Eng.-SE	System Engineering Of Space Instrumentation, Aerospace Systems' Mechanical Design, Mechanical Engineering (Spl. In Machine Design)	PSDN	M.Tech. (2008)
150	Nishant Singh	Sci./Eng.-SD	Electronics Engineer, Design And Development Of Space Based Instruments	PSDN	B.E. (2017)
151	Nishtha Anilkumar	Library Officer-F	Library & Information Services, Facilitating Research For Students And Faculty, Research Output Metrics, Scholarly Communication, Copyright Issues, Library History, Project Management	LIBSR	PhD (2012)
152	P Narendra Babu	Sci./Eng.-SD	Electrical works	CMDV	B.Tech. (2013)
153	P S Patwal	Tech. Officer-C	Electrical Engineering	A&A	D.EL.E (1993)
154	P S Rajput	Sr.Tech.-A	Assistance with Telescope operations	A&A	Ninth (1983)

Sr. No.	Name	Designation	Specialization	Division	Highest Degree Obtained
155	Padia Girishkumar D	Sci./Eng.-SD	Database Administration, Web Application Security Auditing, Applicationvirtualization, Linux Server Administration, Shell Scripting	CNIT	M.Tech. (2013)
156	Pankaj Kumar Kushwaha	Sci./Eng.-SD	Electronics, Development Of low current Electronics Circuit For Space-Borne And Ground Based Scientific Instruments, PCB Designing, Checkout And Automation Of Instruments.	SPASC	B.Tech. (2016)
157	Paramita Dutta	Asst. Professor	Theoretical Physics	THEPH	PhD (2015)
158	Parmar Viral Manubhai	Sci./Eng.-SE	Electrical Engineering - Capital, Minor And Maintenance Electrical Works	CMDV	B.E. (2002)
159	Partha Konar Dy. Head-II, THEPH	Professor	Theoretical Particle Physics, High Energy Collider, Dark Matter, Neutrino, Supersymmetry, Deep Machine Learning	THEPH	PhD (2005)
160	Patel Anil Shivpujan	Technical Assistant.	Maintenance (Electrical)	CMDV	B.E. (2015)
161	Peddireddy Kalyana Srinivasa R	Sci./Eng.-SD	Mechanical Engineer, Payload Design, Structural And Thermal Analysis Of Payload Structures, Computer Based Numerical Simulations, Experimental Simulations Involving High Vacuum Assemblies	PSDN	B.Tech. (2016)
162	Piyush Sharma	Sci./Eng.-SD	Design Electronics For Space Based Instruments	PSDN	M.Tech. (2017)
163	Pooja Chandravanshi	Sci./Eng.-SD	Electronics And Communication Engineer, Free Space Quantum Communication, Post Processing Of Quantum Key Distribution (QKD) Protocols, Labview Based Data Acquisition And Automation	AMOPH	B.E. (2016)
164	Prabhaben T Chauhan	Senior Assistant	Dispatch	ADMGN	B.A. (1999)
165	Prachi Vinod Prajapati	Sci./Eng.-SD	Massive Stars-Nonthermal Emission-Particle Acceleration In Astrophysics, Radio Astronomy, NIR-Optical Instrumentation And Observations, Solar System Science	A&A	M.S. (2019)
166	Pradeep Kumar Sharma	Sr. Admn. Officer	General Administration, CISF Matters, Safety and Security, Rajbhasha, Canteen and Catering, Welfare	ADMGN	M.A. (2012)
167	Pradeep Singh Chauhan	Senior Pur. & Stores Officer	International Trade, Contract Law & Management, Government Emarketplace, Service Contracts, Public Procurement	ADMPR	M.Com (2021)
168	Pradip Shivaji Suryawanshi	Sr. Sci. Assistant-A	Ground And Space Based Optical Instrumentation For Ionospheric Studies, Digisonde Data Analysis	SPASC	M.Sc. (2016)
169	Pragya Pandey	Library Officer-C	Information Services & Documentation, Acquisition & Technical Processing, Scientometric Analysis, Library Automation	LIBSR	PhD (2019)
170	Pranav R Adhyaru	Sci./Eng.-SG	Design & Development Of Electronics Hardware And Software For Scientific Applications.	GSDN	B.E. (1991)
171	Prashant Jangid	Sci./Eng.-SD	Web Application Development, Website Development, Web Application Security Auditing, Mathematics, Algorithm, Operating System	CNIT	B.Tech. (2015)
172	Prashant Kumar	Sci./Eng.-SE	Experimental Atomic And Molecular Physics, Laser Plasma Physics, Optical Emission And Mass Spectroscopy, Payload Development	AMOPH	PhD (2020)
173	Pratheeksha Nayak	Sci./Eng.-SD	Radiocarbon Dating Setups, Speleothems, XRD System, Programming, Data Science, Design And Development Of Web Applications For Data Handling, Visualisation And Analysis	GSDN	B.Tech. (2017)
174	Priti K Poddar	Sr. Proj. Assistant	Accounts & Purchase	ADMGN	PGDCA (1993)
175	R A Parmar	Sr. Proj. Attendant	Office attendant	ADMGN	Ninth (1988)
176	R D Deshpande	Registrar & Senior Professor GSDN	Isotope Hydrology, Hydrogeology	GSDN	PhD (2007)
177	R H Kalal	Canteen Boy-C	Canteen Boy -C	ADMGN	Eight (1987)
178	R K Jaroli	Sr. Proj. Assistant	Assistance with office work at USO	USO	B.Com (1987)
179	R P Singh Head, AMOPH	Sr. Professor	Laser Physics, Light Scattering, Singular Optics, Quantum Optics And Quantum Information	AMOPH	PhD (1994)

Sr. No.	Name	Designation	Specialization	Division	Highest Degree Obtained
180	R R Mahajan	Sci./Eng.-SF	Meteorites, Mass Spectrometer, Noble Gas, Nitrogen, Vacuum, Laser, Mars	PSDN	M.Tech. (1997)
181	R R Shah	Sci./Eng.- SG	Instrumentation & Control, Astronomy & Space Appl. Telescope, Satelite Tracking, Pointing, Imaging Space Servilance Simulation And System Development	A&A	M.B.A. (1997)
182	Rahul Pathak	Sci./Eng.-SD	Design And Development Of Electronics For Ground-Based And Space-Borne Instruments. Front-End Processing, Checkout System Design For SCMOS and CMOS, Data Acquisition And Automation	SPASC	B.Tech. (2013)
183	Rahul Sharma	Sci./Eng.-SD	Database Administration (EGPS, COWAA), Networking	CNIT	M.Sc. (2013)
184	Rajendra Kumar Patel	Senior Lv Driver-B	Driver	ADMGN	Eight (1984)
185	Rajesh A Patel	Technician-F	Refridgeration And Air Conditioning Maintenance	CMDV	I.T.I (2014)
186	Rajesh Kumar Kushawaha	Asst. Professor	Atomic, Molecular And Optical Physics: Ultrafast Spectroscopy, Collision Physics, Extreme Photonics & Femtosecond/Attosecond Spectroscopy	AMOPH	PhD (2010)
187	Rajeshkumar G Kaila	Sr.Tech.-A	Operating & Programing VMC/ TMC Machine Using Mastercam Software, Design And Fabrication Of User Specific Scientific Jobs, And Working On Conventional Lathe/ Milling Machines	WORSH	CC (2000)
188	Rajiv Ranjan Bharti	Sci./Eng.-SD	Planetary Remote Sensing	PSDN	M.Sc. (2003)
189	Rakeshkumar G Mahar	Sr.Tech.-A	Design And Fabrication Of User Specific Scientific Jobs	CMDV	I.T.I (1998)
190	Ram Lakhan Agrawal	Sci./Eng.-SD	Conventional Lathe And Milling Machines	CMDV	B.Tech. (2013)
191	Ramitendranath Bhattacharyya Dy. Head-II, USO	Professor	Solar Physics, Dynamics Of The Solar Corona, Magnetic Reconnection, Numerical Simulation.	USO	PhD (2006)
192	Rashmi	Sci./Eng.-SC	Design And Development Of Space Based Instruments.	PSDN	B.Tech. (2019)
193	Rashmi Ranjan	Sr. Purchase & Stores Officer	Stores, Purchase, Sale, Administration, Account, Computer Applications, Dgs&D Contract	ADMST	M.A. (2011)
194	Ravi Bhushan	Sr. Professor	Oceanography, Paleoclimate, Ocean Biogeochemistry, AMS Radiocarbon Dating, Cosmogenic Radionuclide Application	GSDN	PhD (2009)
195	Ravindra Pratap Singh	Sci./Eng.-SF	MLT Dynamics, Coupling of Atmospheres, Airglow, Atmospheric Waves, Optical/IR Instrumentation	SPASC	PhD (2018)
196	Richa Prashant Kumar	Senior Catering Manager	Catering, Hospitality And Estate Management	ADMGN	B.Sc. (2009)
197	Rishikesh Sharma	Sr. Sci./Eng.-SC	High-Resolution Spectroscopy And Photometric Data Reduction And Analysis, Characterization Of Exoplanets, Astronomical Instrumentation	A&A	M.Sc. (2017)
198	Rishitosh Kumar Sinha	Sci./Eng.-SE	Planetary Remote Sensing Data Analysis Of Mars And Moon	PSDN	M.Tech. (2011)
199	Rohan Eugene Louis	Asst. Professor	Solar Physics	USO	PhD (2011)
200	Rohit Meena	Sci. Assistant	Atmospheric Science: Aerosol Chemistry, Composition, And Characteristics	GSDN	M.Sc. (2018)
201	Rumkee Dutta	Asst. Director [OL]	Hindi Cell Administration	ADMGN	M.A. (2004)
202	Rutuj Gharate	Sci./Eng.-SC	Electronics And Communication	AMOPH	B.Tech. (2022)
203	S Ramachandran	Sr. Professor	Aerosols, Radiation, and Chemistry-Climate Interactions	SPASC	PhD (1996)
204	S Venkataramani	Sci./Eng.- SG	Atmospheric Science - Trace Gases Related To Ozone In Troposphere	SPASC	M.Sc. (1986)
205	S Vijayan	Asst. Professor	Planetary Remote Sensing	PSDN	PhD (2013)
206	Saba Abbasi	Assistant	Purchase services	ADMST	M.B.A. (2015)
207	Sachindranatha Naik Dy. Head-II, A&A	Professor	High Energy Astronomy And Astrophysics	A&A	PhD (2003)
208	Sachin Gavhare	Technical Assistant	Mechanical Engineering(AC)	CMDV	B.E (2014)
209	Samir V Dani Head, Dispensary	Med. Officer-SF	Medical Management Of Communicable And Non-Communicable Diseases, Specialization In Diabetes Management. Chss Management At Dispensary Level.	DISSR	CC (2018)

Sr. No.	Name	Designation	Specialization	Division	Highest Degree Obtained
210	Sandeep Bhagwandas Manglani	Jr. Pers. Assistant	Stenography & Secretarial Work.	ADMDIR	SHAND (2017)
211	Sandip Hasmukh Doshi	Tech. Officer-D	Technical Work, Maintanace, Installations And Upgradation Of Hardware And Software. Computer Hardware, Lan Based Networking And Set Up.	A&A	Dip. (1982)
212	Sandipkumar Savjibhai Galthara	Sr.Tech.-A	Electrical Maintenance Work	CMDV	D.EL.E (2002)
213	Sangeeta Verma	Sr. Sci. Assistant-A	Geosciences, Stable Isotopes	GSDN	M.Phil. (2008)
214	Sanjay Kumar Mishra	Associate Professor	Plasma Physics, Complex (Dusty) Plasmas, Planetary Plasma Atmosphere: Airless Bodies (Like Moon), Theory, Modeling & Implications.	PSDN	PhD (2009)
215	Sanjay S Wairagade Head, CMG	Sci./Eng.-SF	Construction And Maintenance	CMDV	B.E. (1993)
216	Sanjeev Kumar Head, GSDN	Professor	Biogeochemistry, Stable Isotopes, Climate And Environmental Change	GSDN	PhD (2006)
217	Sanjeev Kumar Mishra	Sci./Eng.-SD	Electronics Design, Development And Testing For Space-Based Applications, Numerical Calculation/Simulation, Data Analysis Using Numerical Methods.	PSDN	B.Tech. (2016)
218	Santosh V Vadawale Dy. Head-I, A&A	Professor	X-Ray Astronomy, Black Hole Binaries, Solar X-Ray Astronomy, Instrumentation Related To X-Ray Astronomy And Solar / Planetary X-Rays, X-Ray Polarimetry, X-Ray Optics	A&A	PhD (2003)
219	Satyajit Seth	Asst. Professor	Theoretical High Energy Physics	THEPH	PhD (2014)
220	Satyendra Nath Gupta	Asst. Professor	Atomic Molecular and Optical Physics	AMOPH	PhD (2018)
221	Saurabh Suman	Jr. Pers. Assistant	Secretarial And Administrative Work	ADMDN	M.A Geography (2022)
222	Senthil Babu T.J.	Sr. Admn. Officer	All Establishment & Service Matters, General Administration	ADMGN	B.Sc. (1995)
223	Shaileshgiri I Goswami	Technician-F	Electrical Maintenance	CMDV	I.T.I (2013)
224	Shanmugam M Dy. Head-I, PSDN	Sci./Eng.-SF	Electronics Engineer, Design And Development of Space Instruments	PSDN	PhD (2017)
225	Shashank Urmalia	Sci./Eng.-SD	Mechanical Design For Ground Based And Space Instruments.	SPASC	B.E. (2014)
226	Shashi Kant	Assistant	CMG Office Assistantance	CMDV	B.Sc. (2016)
227	Shashikiran Ganesh	Professor	Milky Way Galaxy, Comets, Astronomical Instrumentation, Polarimetry	A&A	PhD (2010)
228	Shashi Prabhakar	Asst. Professor	Atomic Molecular and Optical Physics	AMOPH	PhD (2015)
229	Shibu K Mathew Head, USO	Sr. Professor	Solar Physics Solar Instrumentation	USO	PhD (1999)
230	Shital Hitesh Patel	Med. Officer-SF	Medical Management of Communicable And Non-Communicable Diseases	DISSR	M.D (1999)
231	Shivansh Verma	Sci./Eng.-SC	Geosciences	GSDN	MS (Integrated) (2021)
232	Shivanshi Gupta	Sci./Eng.-SC	Atomic, Molecular and Optical Physics	AMOPH	MS (Integrated) (2021)
233	Shiv Kumar Goyal	Sci./Eng.-SF	Planetary And Space Instrumentation For Radiation Measurements (Charged Particles, X-Rays, Gamma-Rays) And Mass Spectrometer	PSDN	M.Tech. (2019)
234	Shreeya Natrajan	Sci./Eng.-SC	Organic Studies In Meteorites, Isotope Cosmochemistry, Spectroscopic Studies	PSDN	M.Tech. (2019)
235	Shreya Mishra	Sci./Eng.-SC	Atomic Molecular and Optical Physics	AMOPH	B.Tech. (2021)
236	Shreya Pandey	Assistant	Specialisation In PRL External Project Accounting, Preparation Of Fucs & Monthly Coins Compilation	ADMAC	M.Com. (2019)
237	Shubhra Sharma	Asst. Professor	Quaternary Geology, Geomorphology	GSDN	PhD (2017)
238	Sneha Nair	Senior Assistant	Administration & Office Work	SPASC	M.Sc. (2012)
239	Som Kumar Sharma Dy. Head-II, SPASC	Professor	Atmospheric Dynamics, Weather And Climate, Long Term Changes, Lidar Probing Of Atmosphere	SPASC	PhD (2010)

Sr. No.	Name	Designation	Specialization	Division	Highest Degree Obtained
240	Somabhai N Koted	Sr. Proj. Attendant	Cleaner and assistance in Director's office	ADMDIR	Fifth (1990)
241	Sonam Jitarwal	Sci./Eng.-SD	Electronics Engineer, Design And Development Of Space Based Instruments	PSDN	M.Tech. (2019)
242	Soumya Kohli	Sci./Eng.-SC	Astronomy & Astrophysics	A&A	M.S.(Integrated) (2022)
243	Srirag Narayanan Nambiar	Sci./Eng.-SD	Planetary Science, Ablation Physics, Numerical Modelling, Space Instrumentation	PSDN	B.E. (2017)
244	Srishti Sharma	Sci./Eng.-SD	Web Application Development, Database Management	CNIT	B.Tech. (2012)
245	Srubabati Goswami FNA, FASc, FNASc,FTWAS Head, THEPH	Sr. Professor	High Energy Physics	THEPH	PhD (1998)
246	Sujata Krishna	Sr. Proj. Attendant	Office assistance	ADMGN	S.S.C (1982)
247	Sunil D Hansrajani	Sr. Proj. Assistant	Stores / Purchase; Administration / Accounts	ADMST	B.Com (1991)
248	Sunil Kumar Singh FNA, FNASc	Professor	Isotope And Elemental Geochemistry	GSDN	PhD (1999)
249	Suraj Kumar	Assistant	General Administration	ADMGN	B.Com (2015)
250	Sureshkumar K Patel	Senior Accounts Officer	Accounts services	ADMAC	M.Com (2014)
251	Sushil Kumar	Sci./Eng.-SD	Electronics Engineer: Design And Development Of Space Related Instruments	PSDN	B.Tech. (2014)
252	Suthar Pramodkumar	Technician-G	Workshop services	WORSH	D.M.E. (2016)
253	Swetapuspa Soumyashree	Sci./Eng.-SD	Laser Induced Breakdown Spectroscopy, Plasma Imaging, Femtosecond Physics,Payload Related Simulation In Simion And Comsol, Matlab Coding	AMOPH	B.E. (2017)
254	T A Rajesh	Sci./Eng.-SF	Atmospheric Aerosols, Black Carbon Aerosol Source Apportionment, Aerosol Radiative Forcing, Aerosol Chamber Experiment, Aerosol Instrumentation	SPASC	PhD (2019)
255	T K Sunilkumar	Sr. Tech. Assistant-D	Maintenance of trace gas analyzers	SPASC	B.Pharm (1991)
256	T. S. Neethu	Sr. Proj. Assistant	Administration And Stores	ADMST	M.Com (2007)
257	Tejas Narendra Sarvaiya Dy. Head, CNIT	Sci./Eng.-SF	Cyber Security, Server Virtualization, Linux/Unix Sysadmin, Network Administration, Shell Scripting, Website/Server Auditing.	CNIT	M.E. (2014)
258	Tinkal Ladiya	Sci./Eng.-SC	Electronics Design And Development For Space And Ground Application Instruments	PSDN	AMIE (2020)
259	V H Chavda	Technician-G	Masonary	CMDV	Ninth (1980)
260	V R Patel	Sr.Tech.-A	Workshop services	WORSH	Twelve (1985)
261	Vaibhav Dixit	Sci./Eng.-SE	Optical Designing, Astronomical Instrumentation, Adaptive Optics, H/W-S/W Interface, Data Analysis Pipeline, Simulation Software Development, Parallel Programing, Ai, Deep Learning, Linux Real-Time Scheduling	A&A	M.Tech. (2017)
262	Vaibhav Varish Singh Rathore	Sci./Eng.-SD	Cyber Security, Linux And Unix System Admin, Network Management, Virtulization, Sever/Website Audit	CNIT	B.Tech. (2017)
263	Varun Sheel Head, PSDN	Senior Professor	Modeling Planetary Atmospheres	PSDN	PhD (1996)
264	Veeresh Singh	Asst. Professor	Active Galactic Nuclei (Agn) And Their Evolution, Radio Astronomy	A&A	PhD (2012)
265	Vijaysinh Mansinh Rathod	Sr.Tech.-A	Electrical Repair and Maintance Works	CMDV	H.Sc. (1996)
266	Vikram Goyal	Sr. Sci. Assistant-A	Planetary Sciences, Isotope Cosmochemistry	PSDN	M.Sc. (2016)
267	Vimlesh Kumar	Sci./Eng.-SD	Mechanical, Photonics, Nonlinear Optics, Single Photons, Quantum Optics, Structured Optical Beams	AMOPH	B.Tech. (2016)
268	Vinayak Kumar	Sci./Eng.-SD	Astrophysics, Programming	AMOPH	B.Tech. (2013)
269	Vineet Goswami	Asst. Professor	Isotope Geochemistry, Geochronology, Chemical Oceanography, Non-Traditional Metal Stable Isotope Geochemistry, Inverse Modelling, Mass Spectrometry	GSDN	PhD (2012)

Sr. No.	Name	Designation	Specialization	Division	Highest Degree Obtained
270	Virendra Kumar Padhya	Sci./Eng.-SD	Hydrology and IWIN Mass Spectrometery	GSDN	M.Tech. (2013)
271	Vishal Joshi	Asst. Professor	Astronomy & Astrophysics	A&A	PhD (2014)
272	Vishnu Kumar Dhaker	Sr. Sci. Assistant-A	Atmospheric Aerosols	SPASC	M.Sc. (2016)
273	Vishnubhai R Patel	Sci./Eng.-SC	In CAD Disign,CAM Programming, workshop services	WORSH	B.E. (2018)
274	Vivek Kumar Mishra	Sci./Eng.-SD	Mechanical Design,Telescope Mirror Coating & Cleaning,Mechanical Maintainance Of Eqipments	A&A	B.E. (2015)
275	Yogita Kadlag	Asst. Professor	Isotope Geology, Cosmochemistry and Mass Spectrometry	GSDN	PhD (2015)
276	Yugal Surendra Kumar Jain	Sr. Accounts Officer	Finance, Taxation, Accounts Budget And Audit	ADMAC	MBA(2009), CA (2013)











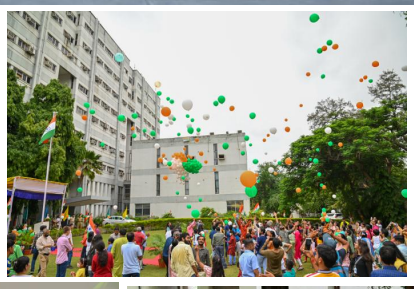


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"समाज की वास्तविक समस्याओं पर विज्ञान और वैज्ञानिकों के अनुप्रयोग के लिए परिस्थितियाँ बनाने के लिए, हमें वैज्ञानिकों को उनकी विशेषज्ञता के क्षेत्र से बाहर की समस्याओं में रुचि लेने के लिए प्रोत्साहित करना होगा।"

-डॉ. विक्रम ए. साराभाई

"To create conditions for the application of science and scientists to the real problems of society, we have to encourage scientists to interest themselves in problems outside their field of specialization."

-Dr. Vikram A. Sarabhai