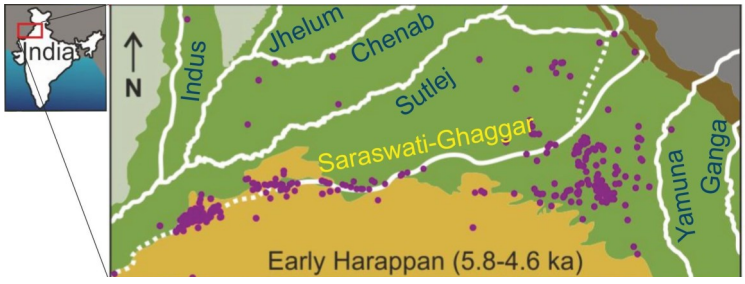
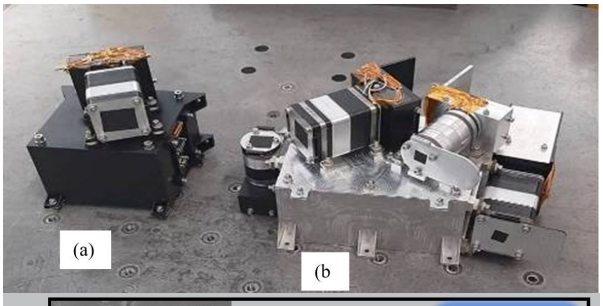
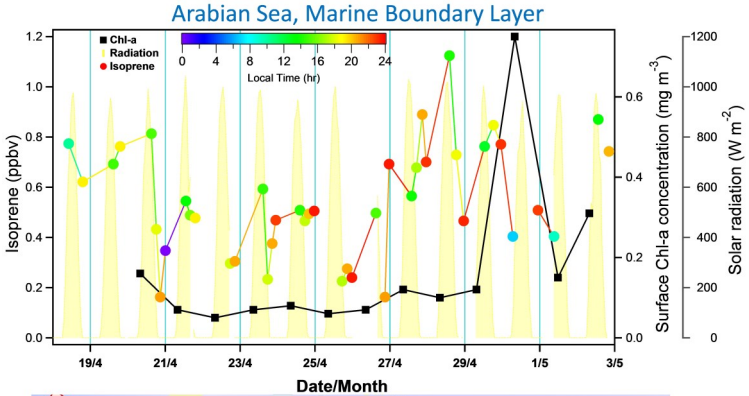
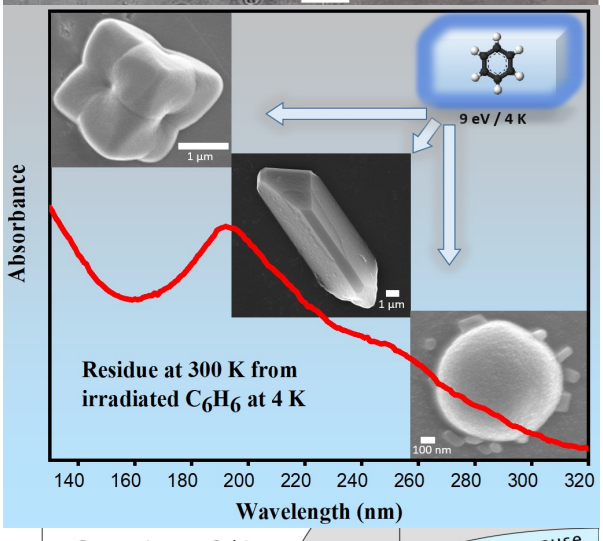
# भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद

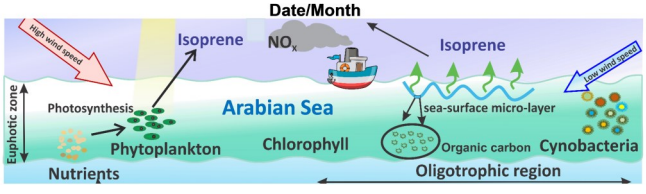
# Physical Research Laboratory, Ahmedabad

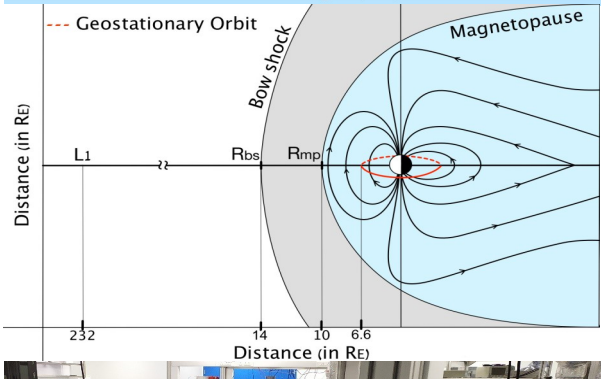


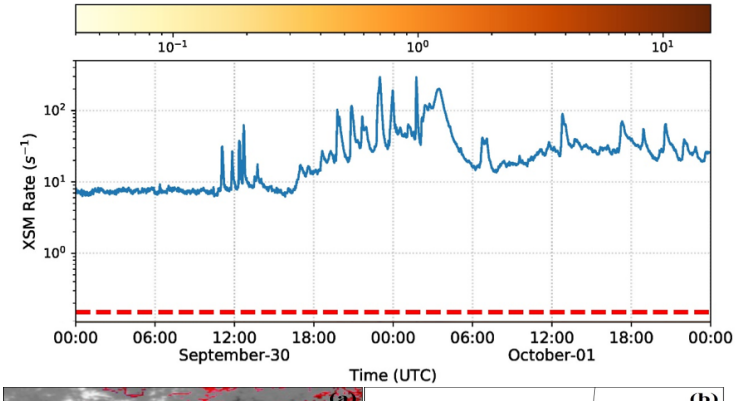



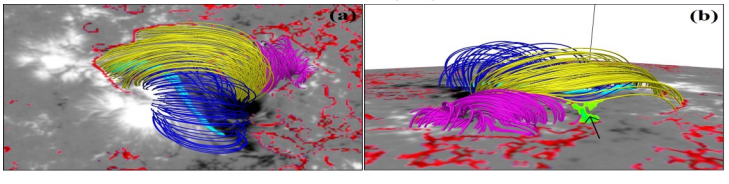




## वार्षिक प्रतिवेदन

## Annual Report

## 2019-2020

**Front cover page:**

**Top Right Panel:** Supra Thermal & Energetic Particle Spectrometer (STEPS) - Subsystem of ASPEX payload model

**Top Left Panel:** The River Saraswati used to flow perennially in the Harappan landscape of NW India during 9,000 to 4,500 years before present

**Center Right Panel:** Geometric shaped residue synthesized by irradiating benzene ice in astrochemical icy conditions.

**Center Left Panel:** Sea-air exchange of isoprene is controlled by ocean productivity and meteorological conditions
**Center Middle Right Panel:** A schematic of the stand-off distance of the MP (Rmp) and BS (Rbs) in the GSM coordinate system. The dotted red circle is the geostationary orbit at 6.6 earth radii (RE). Rmp boundary changed from 9-11 RE during 1976 to 2020.

**Center Middle Left Panel:** X-ray Spectroscopy of the Sun with Chandrayaan-2 Solar X-ray Monitor, Light curve

**Bottom Left Panel:** Identification of pre-flare processes and their possible role in driving a large-scale flux rope eruption with complex M−class flare in the active region NOAA 12371

**Bottom right Panel:** Femtosecond Laser Laboratory, AMOPH division, PRL

**Inside back cover pages:** Events at PRL

**Back cover page:** Dr. Vikram Sarabhai Birth Centenary Logo

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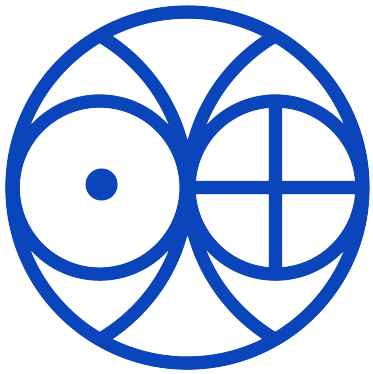
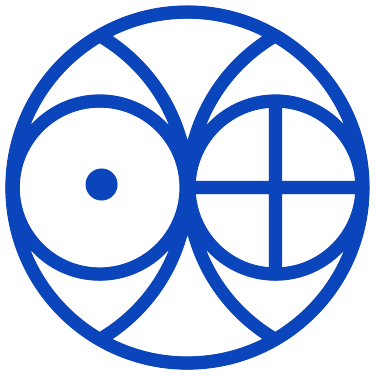


# Annual Report

# 2019 – 2020



**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**

Shri A. S. Kiran Kumar — Chairman
Antariksh Bhavan, New BEL Road
Bengaluru-560231

Dr. K. Sivan, Secretary, Department of Space, Govt. of India — Member
Chairman, ISRO
Bengaluru-560231

Shri Anoop Srivastava, JS & FA, DoS — Member
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Bengaluru-560231

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**A nominee of Ahmedabad Education Society**

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**Director, Physical Research Laboratory**

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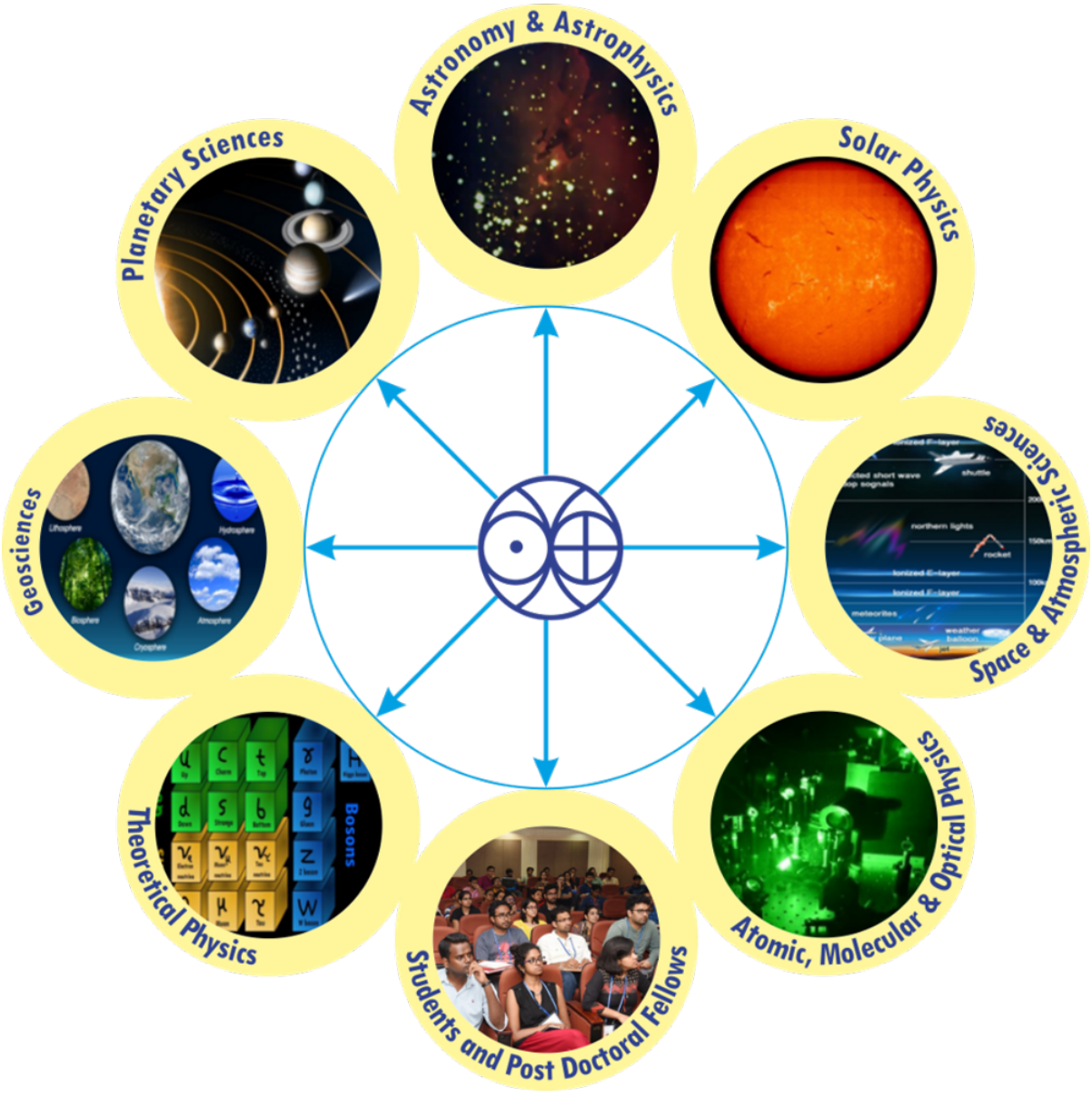
**Registrar, Physical Research Laboratory**

Mr. C. V. R. G. Deekshitulu — Member (Ex-Officio)

# Areas of Scientific Research and Activities



# Contents

# From The Director's Desk

The year 2019-2020 is the Birth Centenary year of Dr. Vikram A. Sarabhai, the founder of PRL and the father of Indian space program. In tune with Dr. Sarabhai's vision, we celebrated this year with several activities meant to promote and inculcate the spirit of innovation and kindle curiosity in the young minds. Our research contributions during the year were also befitting his inquisitive spirit, with several insightful results in various domains of science pursued by PRL. The centenary year festivity started on his $100^{th}$ birth anniversary on $12^{th}$ August 2019 in PRL with participation of several dignitaries, well known personalities, ISRO, DOS and PRL colleagues, and special invitees.

The Parliamentary Standing Committee on Science and Technology, Environment, Forests and Climate Change visited PRL on the 30 December, 2019. The Honourable Members of Parliament, and in particular the Chairman, of the Parliamentary Standing Committee showed keen interest in our research activities, visited few laboratories, interacted with scientists, and appreciated the cutting edge research in various fields spanning from the cosmos to deeper into oceans.

This year PRL contributed 214 peer-reviewed scientific publications, and its 11 researchers were awarded Ph.D. degrees. Exemplary work continues to be the hallmark of scientific research conducted along with the robust training of young scientists through the vibrant Research Fellows and Post-Doctoral programs. This year the list of coveted awards and recognitions span from national Academy Fellowship to the international Young Scientist/Early Career awards. It is a matter of pride that PRL woman scientist was one among the five international young scientists featured in the prestigious journal Natures story on "These young scientists will shape the next 50 years of Moon research". Several colleagues received invitations to serve as members of editorial boards of national and international peer-reviewed journals, board of studies in universities, science advisory committees, and governing council of institutes. Over 150 invitations were received by PRL faculty to deliver plenary or invited talks in conferences or symposia, universities and institutes, which articulate well the leadership role played by PRL scientists in their respective fields of research, both internationally and nationally.

PRL's three science experiments were flown on the Chandrayaan-2 mission to the Moon, viz., Solar X-ray Monitor (XSM) on the Orbiter, Alpha Particle X-rays Spectrometer (APXS) on the Rover, and Chandra's Thermophysical Experiment (ChaSTE) on the Lander. The XSM aboard Chandrayaan-2 orbiter mission is performing exceedingly well and has produced the most sensitive data, even of sub A-class solar flares, which is by far the best across similar space-based experiments in the world. The ASPEX instrument for Aditya-L1 solar mission is in advanced stage of completion for its flight model. The work is progressing well with regard to design considerations and engineering models of various payloads for the ISRO's future planetary and space missions.

New instruments are built in-house and commissioned at different strategic observational locations. Advanced Femto-second laser Lab is established for studying ultrafast atomic processes. The progress with the construction of the new 2.5m telescope facility at Mt. Abu and the back-end instruments is encouraging. The newly developed MFOSC-P instrument is successfully commissioned on the PRL 1.2m Mt. Abu telescope, and the first science result on M-dwarfs is obtained.

Although, theoretically a black hole can have either positive or negative spin with respect to that of the accretion disk, observationally almost all black holes show positive spin. Using a detailed X-ray spectroscopic analysis, it is shown for the first time that the black hole in an X-ray binary system MAXI J1659152 has a negative spin. Extensive measurements using PARAS at 1.2m Mt. Abu telescope have led to the discovery of a brown dwarf, which are astrophysical bodies that are neither planets nor stars. Only less than 25 such sources are known to date. The concept of chemisorption is used to study the formation of molecules in astrophysical environments, which will improve the molecular abundances in astrophysical environments having dust temperature above 200 K such as, protoplanetary disks, carbon stars, planetary atmospheres, among others.

A comparative study of interplanetary coronal mass ejections observed in solar cycle 23 and 24 shows that although their number

in the solar cycle 24 was less compared to the previous cycle, the fraction of magnetic clouds were much higher. Analysis of the variability of rotation periods of solar coronal layers with respect to temperature, using full disk AIA/SDO solar images in six different wavelengths, reveals that sidereal rotation periods of different coronal layers decrease with increasing temperature.

Unusually large electric field disturbances in the dip-equatorial ionosphere are observed when two consecutive interplanetary coronal mass ejections hit the terrestrial magnetosphere resulting in a strong geomagnetic storm during 6-8 September 2017. These unusually large electric field perturbations caused significant changes in the ionospheric current and vertical drifts as well as plasma fountain over low-latitudes ionosphere.

The temporal and spatial variability of chemical mechanisms is studied for the Martian atmosphere. It is observed that ozone is in photochemical equilibrium up to $\sim$30 km (aphelion) and $\sim$45 km (perihelion) for which hygropause is proposed as a marker for ozone seasonal variability. New model of regolith and water ice (volatile) mass escape rates due to micrometeorite impact are developed using Galileo observations of dust near Moon. This has relevance as the Moon loses its water ice at a rate of around 6.3 kg per year due to the micrometeorite impact.

The relation between the levels of important oceanic biogenic volatile organic compounds, such as, isoprene and light alkenes in marine air and the physical and biological parameters of surface seawater of the Arabian Sea has been established. Large emissions of such volatile compounds from the oligotrophic water highlight the implications of the Arabian Sea 'Paradox' on regional atmospheric chemistry in view of elevated emissions of these biogenic volatile organic compounds from seawater and NOx from shipping activities.

Determining sources of sediments deposited by the ancient Ghaggar river in the north-western India, it was discovered that during 80-20 ka and 9-4.5 ka the river was receiving sediments from the glaciated Higher Himalayas, thus making it perennial. This study also finds that during the latter active phase of the river the Early Harappans built their settlements along its banks. From optical dating techniques, it is inferred that the mid-latitude westerlies, and not the Indian summer monsoon, are the major source of moisture for the glaciers in the north-western Himalayas in the past as well as in the present. The study has implication in modelling the future predictions of the glacier mass balance under the global warming scenario.

Effect of vorticity on the evolution of the quark gluon plasma is studied. It was shown that inclusion of spin polarisation in the presence of vorticity leads to faster cooling of quark gluon plasma as well as a suppression of dilepton production from it. The physical nature of the aromatic residue left over by 9 eV photon irradiation of benzene ices was found to contain micron-sized particles of different shapes. This work shows that geometrical shaped dust may be a significant component of the interstellar medium. High quality research in the area of quantum science is continuing. A simple technique is demonstrated to control the orbital angular momentum of light for the generation of higher dimensional entanglement as required for secured quantum communication.

PRL continued with zeal its activities towards outreach and popularization of science at various levels and fora. Vikram Sarabhai Innovation Competition (VISION 2019) is a national level competition organized by PRL to rejoice the birth centenary of Dr. Vikram Sarabhai, in which over 120 innovative science proposals were received from the students of B.Sc., M.Sc. and B.Tech. After proper reviews, including in-person presentations, six of them were shortlisted for project grants. Another pan-India program VOICE (Vikram Sarabhai Competition for Concept) essay writing for school children received about 1000 essays from 24 states of India, with more than half participants being girl students. About 50 students from different age groups were invited to PRL to explain the concept of their essays and prizes were given to the top three in each of the categories.

On $11^{th}$ November 2019, the Seventy Second Foundation day of PRL was commemorated with the inspiring award ceremony for the Shri Hari Om Ashram Prerit Senior Scientist Award, the Hari Om Ashram Prerit Dr. Vikram Sarabhai Research Awards in the fields of Space Sciences, Space Applications, and Electronics Informatics, Telematics & Automation, the PRL award, and the Buti Foundation Award. Eight renowned scientists were honoured with these awards for their excellent scientific contributions. On this day, the bust of Dr. Vikram Sarabhai was unveiled in the Thaltej campus of PRL. PRL's Hindi magazine Vikram Patrika had a special edition with several articles and photo features of Dr. Sarabhai to recount his illustrious personal and professional life.

The National Science Day celebrations saw a high participation of close to 1200 students from the state of Gujarat of which 137 were selected for participation in the program at PRL on the $29^{th}$ February 2020. Five brilliant students were awarded the Aruna Lal Fellowship. Additionally, special efforts were made to popularize science among girl children by inviting more than hundred girl students to PRL. Further, diverse outreach activities were carried out throughout the year, which include a day long program for 50 bright girl students at Udaipur Solar Observatory (USO), and scientific visits by many school and college students to PRL's USO and Mt. Abu observatories. PRL sustained its Science Express movement of visiting different schools in villages of Gujarat and Rajasthan, wherein over 20 different types of live experiments were demonstrated to over 4600 school students, thereby communicating the excitement of studying science.

Our unfettered and relentless efforts towards capacity building continued this year with enhanced vigour. Nearly 50 students, teachers, and summer fellows from Indian Science Academies, spent two-months with our faculty during summer of 2019, advancing their knowledge in basic research and learning about the state of the art ground-based and space-borne experiments. The first 2-months Summer Training School in Planetary Science was conducted for 25 students during May-June 2019. The major meetings and programs organized include, Students Conference in Optics and Photonics (SCOP), ISRO-Structured Training Program (STP), YUVIKA program, PRL Alumni Meet, $2^{nd}$ PRL-IAPT Dr. Vikram Sarabhai Lecture, and first Indian Planetary Science Conference (IPSC-2020). The eleventh United Nations CSSTEAP course on Space and Atmospheric Sciences, with 13 students from 5 countries of Asia-Pacific region, was completed in April 2019. A two-weeks CSSTEAP short course on Space Weather was conducted at PRL in November 2019 for the participants from Asia-Pacific region, wherein 27 members from 12 countries participated. A total of 64 scientific, technical, and administrative staff of PRL have been encouraged to participate in different training programs in India conducted by the educational institutes, universities and the Government to empower them in their professional work.

PRL continues its strong academic and capacity building association with many universities and institutes all over the country, and participated in organizing national and international meetings.

Use of Hindi in all areas of administration and official communications is ensured in PRL. Bilingual communication is encouraged in all administrative orders. The website of PRL is bilingual. The participation in Hindi Pakhwada celebrations continues to rise. This year's celebrations had a session with reminiscences from individuals who worked closely with Dr. Sarabhai, and also, the book "India's Space Pioneer" based on life of Dr. Vikram Sarabhai was released in a function.

In the year of Dr. Vikram Sarabhai's birth centenary we remind ourselves to remain committed to the very spirit of PRL's ethos of research in fundamental science and space exploration leading to a better understanding of the nature. In this endeavour we are constantly encouraged and whole-heartedly supported by Shri. A. S. Kiran Kumar, Chairman, PRL Council of Management, Dr. K. Sivan, Secretary, Department of Space, and all the members of the PRL Council of Management. I gratefully thank them for their astute advices and guidance, and their unflinching faith laid on PRL.

**Anil Bhardwaj**
**Director**

# PRL in News

1. “Residue from vacuum ultraviolet irradiation of benzene ices: Insights into the physical structure of astrophysical dust published in Spectrochimica Acta Part A, was selected for the Cover Page of the AstroPAH Newsletter published by the Leiden Observatory, Leiden University, Netherlands. http://t.ly/7Tos
2. 29 February 2020, Times of India, Gujarat Edition. Press release on our article Survivability of Extremotolerant Bacteria from the Mukundpura Meteorite Impact Crater that was published last year (2019), https://t.ly/ilZ6.
3. Evidence of river Saraswatis existence found?, The Hindu, 07 December, 2019, https://t.ly/Z6KJ
4. “Researchers say drying of Saraswati-like river led to decay of Harappan city”, Hindustan Times, 04 January, 2020, https://t.ly/c4R7
5. “This Himalayan glacier has been advancing, not receding”, Nature India, https://t.ly/jH2K, 03 January, 2020.
6. “These young scientists will shape the next 50 years of Moon research”, Nature News feature, https://t.ly/6E54.

# Science Highlights

### Astronomy and Astrophysics

- The Solar X-ray Monitor (XSM), designed and developed at PRL, is successfully operational on-board Chandrayaan-2. XSM is designed to measure solar X-ray spectrum in the energy range of 1 - 15 keV with high energy resolution (better than 180 eV @ 5.9 keV) and the highest time cadences of one second. Despite very low solar activity due to the present solar minima, XSM is providing very sensitive measurements of solar X-ray spectra and detected many sub A-class flares which no other instrument in the world can detect at present.
- Using Radio data we have estimated the sub-solar stand-off distance of the terrestrial magnetopause and bow shock, and the shape of the magnetopause using numerical as well as empirical models. The computed magnetopause and bow shock stand-off distances have been found to be increasing steadily since around the mid-1990s, consistent with the steady declining trend seen in solar magnetic fields and solar wind micro-turbulence levels. Similarly, we find an expansion in the shape of the magnetopause since 1996. Importantly, we also find two instances between 1968 and 1991 when the magnetopause stand-off distance dropped to values close to 6.6 earth radii, the geostationary orbit, for duration ranging from 9-11 hours and one event in 2005, post 1995 when the decline in photospheric fields began. This is a very important finding as it represents a clear and present danger to our satellite systems in the event of a large CME impact, especially given the fact that very large CMEs have been known to occur in weak solar cycles.
- We have discovered a Brown Dwarf by measuring its mass, which was expressed as a possible candidate source TOI-503b, from NASA's Transiting Exoplanet Survey Satellite (TESS) mission using spectroscopic data from PARAS. The 9 high-resolution spectra acquired from the PARAS spectrograph attached to the 1.2 meter telescope at PRL Observatory, Mount Abu ,during April 06 to April 11, 2019, majorly contributed to the mass-measurement of the brown dwarf. Brown Dwarfs are astrophysical bodies that are neither planets nor stars. Their masses lay between 13 Jupiter mass to 80 Jupiter mass and are extremely rare to find in the Universe (about less than 25 such sources still date are known). The mass of the brown dwarf measured by PARAS was found to be around 55 Jupiter mass and its discovery is significant.
- Stars are formed in molecular clouds that are widely present in our Galaxy. The space-based infrared and ground based sub-millimeter (sub-mm) data have unveiled numerous filamentary features in molecular clouds, where signatures of star formation activities are observed. The physical mechanisms of filament fragmentation and the role of filaments in the formation of dense massive star-forming clumps and young stellar clusters are still debated. In this context, some existing models for the long, but finite-sized, filaments predict that the fragmentation and collapse can take place at the ends of the filaments (i.e., end-dominated collapse), where the gas has an enhanced acceleration. However, observational assessment of such existing numerical simulations is very limited in the literature. In this connection, an embedded filamentary structure in a massive star-forming region, LBN 182.30+00.07 or Sh 2-242 (hereafter S242) has been studied. Dense molecular cores as well as a large number of young stellar objects are observed mainly toward the filament ends. An oscillatory pattern in velocity is also observed toward the filament, indicating its fragmentation. Considering our observed results, the S242 filament is a very good example of the end-dominated collapse for formation of new stars.
- We measured the radius of a black body emitting region. Broad-band timing and spectral studies of accretion powered Be/X-ray binary pulsar 2S 1417-624 was carried out by using data from Swift and NuSTAR space based observatories. The observations were carried out at the peak of a giant outburst in 2018. X-ray pulsations at 17.475 s were detected in the light curves up to 79 keV. The evolution of pulse profiles with energy was found to be complex a four-peaked profile at lower energies gradually evolved into a double-peak structure at higher energies. The broad-band spectrum of the pulsar is well described by a composite model consisting of a cut-off power-law model modified with the interstellar absorption, a thermal black-body component and a Gaussian function for the 6.4 keV iron emission line. The radius of the black-body emitting region was estimated to be $\sim$2 km, suggesting that the most probable site of its origin is the stellar surface of the neutron star.
- The astrophysical black holes are characterized by two parameters, mass (M) and angular momentum (denoted by a dimensionless spin parameter, a). Theoretically the black hole can have either positive or negative spin (i.e. rotating in the same or opposite direction to that of the accretion disk), however, observationally almost all black holes show positive spin. We have shown for the first time, using a detailed X-ray spectroscopic analysis, that the black hole in an X-ray binary system MAXI J1659-152 has a negative spin.

### Solar Physics

- Observations provide evidence of distinct rebuild-up of net Lorentz force in between the successive flares and its abrupt downward changes during each flare in solar active regions. This evolutionary pattern of net Lorentz force which is responsible for the build-up and magnetic energy release

has significant implications for the forecasting of recurrent large eruptive flares from the same active region and hence the chances of interaction between the associated CMEs.

- By implementing automatic detection algorithm for solar filaments on full disk H$\alpha$ images, the time of initiation of eruption of filaments can be estimated. These timings when compared with that of associated flare observed in EUV help to establish the temporal connection of eruption filaments, as precursors to flares and CMEs and hence is useful for space weather assessment.
- Observations of small-scale precursor activities leading to the destabilization of a meta-stable flux rope suggests that pre-flare emission can be initiated by locations of strong photospheric current of opposite sign situated adjacent to each other and further a series of such small-scale activities can eventually lead to triggering of a flux rope eruption.
- A comparative study of interplanetary coronal mass ejections (ICMEs) observed in solar cycle (SC) 23 & 24, shows that although the number of ICME events in SC24 was less compared to the previous cycle, the fraction of magnetic clouds was much higher during SC24 than SC23 (60% to 41%). The analysis of magnetic clouds and ejecta observed in the same cycle, supports the hypothesis that all CMEs have a flux rope structure and that the trajectory of the CMEs essentially determines the observed ICME structure at 1 AU.
- Analysis of variability of rotation periods of solar coronal layers with respect to temperature (or, height) using full disk AIA/SDO solar images in six different wavelengths, reveals that sidereal rotation periods of different coronal layers decrease with increasing temperature (or, height).

**Planetary Sciences**

- A new algorithm, robust with respect to space weathering effect, is developed to derive global maps of iron, calcium and magnesium up to 140 m resolution using the Chandrayaan-1 $M^3$ data. The new elemental maps are largely free of artifacts in immature areas. Our estimated elemental abundances are in line with the results from Apollo and Lunar missions and the maps could be interesting for quantitative geochemical information.
- An unusually bright structure of 1800 $km^2$ is found on the lunar, equatorial farside near Dufay crater, which has strong 3-$\mu$m absorption feature. The feature is 30 % stronger than surrounding at the local midday and it is unique of its kind. The structure could be due to a thin layer formed by the recent fall of meteoritic/cometary material with high OH/$H_2O$ content, being detectable by its pronounced 3-$\mu$m absorption band.
- The Ramgarh structure in Rajasthan has been identified as third, confirmed asteroid impact crater in India (after Lonar and Dhala). This remnant, complex structure was excavated in sedimentary target rocks involving carbonates (Vindhyan Supergroup).
- Five new skylights have been discovered in the Hebrus Valles region of Mars (20$^\circ$40'31.9" N, 126$^\circ$23'56.2" E) using remote sensing data from MRO (Mars Reconnaissance Orbiter; NASA) and Mars Odyssey (NASA). These are indicative of presence of caves in the subsurface, which are sites of scientific importance for future exploration of the Red planet due to their astrobiological significance.
- Temporal and spatial variability of chemical mechanisms are studied for the Martian atmosphere. It is observed that $O_3$ is in photochemical equilibrium up to $\sim$30 km (aphelion) and up to 45 km (perihelion), for which hygropause is proposed as a marker for ozone seasonal variability.
- Total columnar ozone and dust are retrieved from the Mars Express spectral data for two Martian years. In southern tropical latitudes, columnar $O_3$ is increased during the MY28 global dust storm, indicating radiative impact of dust on $O_3$. From GCM/SPICAM observations, atmospheric dynamics is found to have more effect on $O_3$ during during winter over the southern polar region.
- A photochemical model is developed to study the forbidden atomic carbon, nitrogen and oxygen optical emission lines in comet C/2016 R2. The mean photodissociation yield of CO, producing $\sim$1 % C($^1$S) and difficult to measure in lab, is constrained using the model and observations. In this water-depleted comet, $CO_2$ can be a significant production source of atomic oxygen. The first-ever observed emissions and the modelling works suggest radial transport to be the dominant loss mechanism for N($^2$D) in the coma.
- A model to study photochemical processes of ultraviolet atomic line emissions in comet 67P is developed. Assuming electron impact to be the only excitation mechanism, the Rosetta Alice spectrometer observations are used to derive the electron density. Our modelling results suggest the observed HI, OI and CI emission lines being controlled by photodissociation of neutrals rather than electron impact excitation as thought earlier, when the comet has a gas production rate of $10^{27}$ $s^{-1}$ or more.
- New models of regolith and water ice (volatile) mass escape rates due to micrometeorite impact are developed for the first time, using Galileo dust observations. Upper limits of mass escape rates of regolith and water ice for the micrometeorites in the range from $10^{-21}$ to $10^{-1}$ kg are $\sim$2.218 $\times$ $10^{-4}$ kg/s and $\sim$1.988 $\times$ $10^{-7}$ kg/s, respectively. Moon loses its water ice (volatile) at a rate of $\sim$6.271 kg/year due to the micrometeorite impact.
- Venus Express observations of whistler mode waves around 250 km altitude were analysed. The results demonstrated the presence of lightning source below the ionosphere.
- This is for the first time the concept of chemisorption is used to study the formation of molecules in the astrophysical environments. Depending upon the depth of the potential well of the chemisorption site, it can form molecules up to 800 K or more. Until this work, astrochemical models treated grain surface chemistry solely by physisorption which is only efficient at low temperatures ($<$ 200 K). Thus the use of chemisorption will improve the molecular abundances in astrophysical environments having dust temperature above 200 K, e.g., protoplanetary disks, carbon stars, planetary atmospheres, among others.
- ChaSTE payload was reliased in collaboration with SPL/VSSC and flown on board Chandrayaan-2 lander. The payload was switched few times during the cruise phase as a part of health check tests. The temperature measurements obtained along the ChaSTE probe were analysed and the performance of was found to be good.

**Space and Atmospheric Sciences**

- The variations in the aerosol-induced atmospheric heating rate that arise due to the differences in the chemical composition of aerosols (single scattering albedo) on temporal (season), spatial (urban vs. high altitude remote) and on vertical (surface vs. column) scales obtained over the same region over distinct environments (locations), provide regional bounds for aerosol radiative effects, and will be crucial for regional climate impact assessment.
- Results show that the mixing characteristics of refractory black carbon aerosols are different for different sizes of particles which would result in large variations in the physicochemical properties (i.e., hygroscopic and optical properties) of aerosols. These findings from an urban location in the tropics, the first and unique, are crucial for determining the impact of black carbon aerosols on cloud condensation nuclei activation process, and can serve as inputs in climate models for aerosol-cloud-radiation interaction studies.
- The sea-air flux of biogenic volatile organic compounds (BVOCs) and transformation in the atmosphere lead to the production of ozone and organic aerosols. In our recent studies over the Arabian Sea, the relations between the levels of important oceanic BVOCs such as isoprene and light alkenes in marine air and the physical and biological parameters of surface seawater of the Arabian Sea were established. In this interdisciplinary study, seawater parameters are used to explain the distribution of isoprene in the atmosphere over the highly productive and oxygen-deficient region of the Arabian Sea. The findings of this study suggest strong interactions between marine-derived VOCs with anthropogenic emissions over the northern Indian Ocean, in particular over the Arabian Sea. Large emissions of BVOCs from the oligotrophic water highlight the implications of the Arabian Sea 'Paradox' on regional atmospheric chemistry in view of elevated emissions of BVOC from seawater and NOx from shipping activities.
- Signatures of solar cycle dependence of dominant atmospheric tides are observed in the mesosphere and lower thermosphere over an extratropical station. Both diurnal and semidiurnal tides show high correlation in Autumn and least correlation in Summer. In general, such relationship between the tides and solar flux is found to be most prominent in solar maxima. Further, amplitudes and periods of the quasi-two-day wave exhibit relationship with the solar flux, with higher values in solar minimum as compared to solar maximum.
- Unusually large electric field disturbances in the dip-equatorial ionosphere are observed when two consecutive interplanetary coronal mass ejections (ICMEs) hit the terrestrial magnetosphere resulting in a strong geomagnetic storm during 6-8 September 2017. These unusually large electric field perturbations caused significant changes in the E region current and F region vertical drift as well as plasma fountain over low latitudes. More importantly, the magnitudes of the large electric field perturbations in the equatorial ionosphere cannot be explained by the penetration of the dawn-dusk Interplanetary Electric Field (IEFy) alone. It is shown that substorms can work in tandem with the storm-time electric field perturbations to generate anomalously high impact on the equatorial ionosphere. This work has implication for the evaluation of storm time plasma distribution over low latitudes.
- The least explored relationship of the atmospheric tides and quasi-two-day wave (QTDW) with the solar cycle is investigated from an extra-tropical station. Although such relationship is found to be very weak in nature, high activity is found in solar maxima and minima in case of tides and QTDW, respectively pointing out dissimilar response of different atmospheric waves to the solar long-term variability. Since the detailed underlying physical processes for such peculiar behaviour are unknown at present, further coordinated studies are being sought in this direction.

**Geosciences**

- Determining sources of sediments deposited by the ancient Ghaggar river in the northwestern India, scientists of the Geosciences Division have discovered that during 80-20 and 9-4.5 ka the river was receiving sediments from the glaciated Higher Himalayas, thus making it perennial. The study also finds that during the latter active phase of the river the Early Harappans built their settlements along its banks. It is therefore likely that the ancient Ghaggar of 9-4.5 ka is the river Saraswati of the Rig Veda and other ancient Indian texts. This finding should settle most long-standing controversies on the existence of the river Saraswati.
- A prominent and systematic annual pattern of the isotopic depletion (average $\delta^{18}$O: -2.5‰ in Jun-Jul; -5.2‰ in Aug-Sept) in the second half of the Indian Summer Monsoon (ISM), has been identified based on the long term (2005-2016) daily precipitation isotope data ($\delta^{18}$O, $\delta$D and d-excess) from Ahmedabad. This has been ascribed to: (1) increased contribution of terrestrially recycled vapor; (2) intra-seasonal change in sea-surface, surface-air and cloud base temperatures; (3) increased rain-out fraction from marine vapor parcel; and (4) increase in relative proportion of convective rain.
- Based on the reasonably large number of Cosmogenic Radio Nuclide (CRN) ages along the Indian Himalayan orogen, it was suggested in earlier studies that the Himalayan glaciers in the past were nourished by the Indian Summer Monsoon. However, results from a recent study by PRL employing optical dating technique are not only at variance with the earlier climatic interpretation but have also revealed the limitations of CRN ages in certain specific geological context. This study in Ladakh Himalayan range demonstrated that CRN ages suffer from geological inheritance of the radionuclides used in CRN dating, which if not accounted for, are going to be significantly older than the actual ages of the glacier advances. It is also inferred in this study that the mid-Latitude westerlies, and not the ISM, are the major source of moisture for the glaciers in the NW Himalaya in the past as also in the present. The study has implication in modeling the future prediction of the glacier mass balance under the global warming scenario.
- Controls on production and consumption of nitrogen in terms of nitrogen transformation rates were studied in semi-arid tropical soils from different land-types such as salt flat, grassland, wetland, and agricultural field using $^{15}$N isotope dilution experiments. Soils with no vegetation, high salinity, and high moisture (salt flats) showed significant decline in gross production of nitrogen compared to soils with vegetation, low salinity, and low moisture (grassland, wetland, and agricultural). Salinity was found to be the most important

factor controlling nitrogen transformation rates. Soils in the coastal drylands undergoing frequent seawater exposure or excessive evaporation due to climate change may experience a slowdown in nitrogen cycling due to salinization leading to reduced nutrient production.

**Theoretical Physics**

- Effect of vorticity on the evolution of the quark gluon plasma is studied. It was shown that inclusion of spin polarisation in the presence of vorticity leads to faster cooling of quark gluon plasma as well as a suppression of dilepton production from QGP.
- A nonperturbative attempt was made to estimate drag and diffusion coefficients of heavy quarks in the background of a nontrivial Polyakov loop plasma including effects of viscosity. It was observed that Polyakov loop decrease the drag coefficients and enhances the momentum diffusion coefficients as compared to perturbative QCD estimates.
- Explored the synergy between the proposed atmospheric neutrino experiment INO and long baseline experiment ESS$\nu$SB proposed at Sweden. The later experiment is designed for discovering CP violation in lepton sector with high sensitivity. We have shown how the hierarchy sensitivity of ESS$\nu$SB can be enhanced by adding data from INO and ongoing experiments T2K and NOVA.
- Comprehensive constraints were obtained on a general U(1) extended inverse seesaw model consistent with neutrino oscillation data, electroweak precision data, Electroweak vacuum stability, dark matter and collider constraints. The implications of neutrino less double beta decay in presence of non-standard interactions allowing solar mixing angle to be greater than $\pi/4$ were examined and new predictions for future experiments were made.
- Existence of stable atoms and molecules is due to the stability of proton which is a consequence of some fundamental symmetries of nature. Hypothetical theories which unify strong, weak and electromagnetic forces, known as the grand unified theories (GUTs), predict violation of such symmetries and hence proton decay. We use this strategy to investigate the viability of a particular class of GUTs constructed in six-dimensional spacetime. Our study implies that this class of GUTs predicts proton decay rate large enough to be seen at the ongoing experiments. Moreover, proton decay signals are very different from those predicted by the GUTs in four spacetime.
- In our recent theoretical work we have quantified the properties of the Bose glass phase in the disorderd system of bosons in an optical lattices. We show that the Bose glass phase is robust in these systems and is enhanced in the presence of synthetic magnetic field. The parameter domain identified in our work could be valuable for the experimental realisation of Bose glass phase in optical lattices.
- We theoretically analyse D.C. resistivity in the Kondo-lattice model using the powerful memory function approach. The complete temperature evolution of resistivity is investigated using the Wolfle-Gotze expansion of the memory function. The resistivity in this model originates due to spin-flip magnetic scattering of conduction s-electrons off the quasi-localized d or f electron spins. We find the famous resistivity upturn at lower temperature regime, and in the high temperature regime we discover that resistivity scales as T raise to the power 3/2. The worked out theory is quantitatively compared with experimental data and reasonably good agreement is found.

**Atomic, Molecular and Optical Physics**

- A method utilizing time-resolved LIBS measurements has been developed to obtain the value of Stark broadening, an important parameter for elemental decomposition of a given sample.
- The intensity correlation properties along with photon statistics of twisted single photons carrying different orbital angular momentum were studied which hold importance while using these structures for quantum communication.
- A technique was demonstrated to study nature of nonclassical or quantum sources of light using a simple setup, which could be realised in an undergraduate laboratory. It could be very useful for introducing young students to the field of quantum information processing.
- The enhancement in neutral and ionic emission lines due to aluminum nanoparticles was investigated and it was found that the emission intensity increases with increasing concentration of nanoparticles as well as laser energy.
- The physical nature of the aromatic residue left over by 9 eV photon irradiation of benzene ices was found to contain micron sized particles of different shapes. This work shows that geometrical shaped dust may be a significant component of the ISM.
- A precise limit on a local Lorentz invariance violating parameter of an electron is obtained by combining our highprecision calculations with the measurement. This provides signature of physics beyond the Standard Model of particle physics.
- Multispectral luminescence studies in feldspar were done to overcome the signal fading issues of feldspar.
- Explored the effect of S/N ratio on dose estimations from single grains of quartz. S/N Ratio had significant implication on distribution of doses.
- We have demonstrated a simple technique to control the orbital angular momentum of light for the generation of higher dimensional entanglement as required for secure quantum communication.
- We have demonstrated the generation of vector vortex beam directly from an optical parametric oscillator. Such demonstration has opened up the possibility of the generation of structure optical beams from the source alongwith the benefits of the source itself.
- Although nonlinear frequency conversion is a polarization dependent process, we have demonstrated the possibility of nonlinear frequency conversion of vector vortex beams having varying polarization state.
- An analytic energy derivative approach is developed in the relativistic coupledcluster theory framework to determine the atomic field shift and mass shift factors very reliably. As a proof of concept, this theory is applied to determine the massshift and the fieldshift constants and combining these values with the measurements of isotope shifts in indium atom, nuclear charge radii of the ground and isomeric states of the $^{104-127}$In isotopes are inferred.

# Awards and Honors

**Faculty**

**A S Kiran Kumar**

1. ISRO Lifetime Achievement Award 2019, in recognition of lifetime contributions to the Indian Space Programme.

**Anil Bhardwaj**

2. Awarded J. C. Bose National Fellowship, by DST-SERB, 2019.
3. Elected Fellow, Gujarat Science Academy, 2019.

**Ashok K. Singhvi**

4. Karthik Khillar Memorial Lecture, Pandit Deen Dayal Petroleum University, Raisen, Gandhinagar October 21, 2019.
5. Foundation Day Lecture, Institute of Seismological Research, Raisen, Gandhinagar. May 18, 2019.
6. Invited as a resource person in 5-day National workshop on Luminescence Dating: Methodology and Application held in NGRI, Hyderabad during December 711, 2019.

**S. A. Haider**

7. Awarded “INSA Senior Scientist Position” for the period 2019-2022.
8. Elected Core-member of “Programme Advisory Committee (PAC) on Earth and Atmospheric Sciences & Engineering Research Board (SERB) under DST” for the period 2019-2022.

**P. Janardhan**

9. Elected as a Fellow of the Indian National Science Academy (INSA), 2019.

**Srubabati Goswami**

10. Visited Imperial College London as Lever Hulme Trust Visiting Professor From 1st May to 31st July 2019.

**Duggirala Pallamraju**

11. Invited to serve as Co-leader for the Pillar-2: Space Weather and Earth‘s Atmosphere of the SCOSTEP’s (Scientific Committee on Solar Terrestrial Physics) new program, PRESTO (Predictability of the variable solar-terrestrial coupling) 2020 - 2024.

**S. Ramachandran**

12. Affiliate Scholar, Institute for Advanced Sustainability Studies, Potsdam, Germany.

**Kuljeet K. Marhas**

13. Conferred Fellow, American Geophysical Union, 2019
14. D. Lal Memorial Award: American Geophysical Union, 2019
15. Eminent Mass Spectrometerist: Indian Society of Mass Spectrometry, 2019

**Bhalamurgan Sivaraman**

16. The Royal Society International Exchange Grant, UK. Validity 2019 to 2021

**Lokesh Kumar Sahu**

17. Nodal Faculty for Gujarat, the National Clean Air Programme (NCAP), Ministry of Environment, Forest & Climate Change, 2019.
18. Indian Academy of Sciences-Certificate of Reviewer Excellence 2018 for Journal of Earth System Science (JESS).
19. Outstanding Contribution Certificate in Reviewing 2018 for Planetary and Space Science (PSS).

**Amit Basu Sarbadhikari**

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

**Sanjay K. Mishra**

21. Elected as Young Associate of Indian Academy of Sciences (IASc), Bangalore in 2019.
22. Awarded Indian Physics Association (IPA) Buti Foundation Award for Excellence in Theoretical, Astrophysics, and Biophysics, for the year 2018.

**Anirban Ghosh**

23. Received outstanding poster presentation award for the paper "Nonlinear generation of ultrafast, high power, higher order vector vortex beams" presented in the Summer school in Optics and Applied Photonics, Indian Institute of Science, Bangalore, held during 1721 June 2019.

**Research Scholars**

**Kaustav Chakraborty**

24. Visited Universit de Strasbourg, France with Raman-Charpak Fellowship for two months during May to July 2019.

**Deepak Kumar Karan**

25. International Association for Geomagnetism and Aeronomy (IAGA) Young scientist / Early Career Award for the year 2019, presented in the $27^{th}$ International Union for Geodesy and Geomagnetism (IUGG) General Assembly in Montreal, Quebec, Canada on 15 July 2019. (http://www.iaga-aiga.org/awards-and-honors/young-scientist-award/)

**Varun Sharma**

26. Received travel grant student award in recognition of his outstanding scientific contribution to CLEO/EUROPEEQEC 2019, 2327 June 2019, Munich, Germany from European Physical Society (EPS).
27. Selected to participate in the 69th Lindau Nobel Laureate Meeting taking place from 30 June to 05 July 2019 in Lindau, Germany.

**Rahul K. Kushwaha**

28. The physical nature of the aromatic residue left over by 9 eV photon irradiation of benzene ices was found to contain micron sized particles of different shapes. This work shows that geometrical shaped dust may be a significant component of the ISM.

# Recognition, Best paper & Thesis awards

**Faculty**

**Anil Bhardwaj**

1. President, Indian Committee of URSI-International Union of Radio Sciences, 2020-2023.
2. Delegation Leader, Indo-Israel Astrophysics and Planetary Science workshop - Israel Dec. 23, 2019.
3. Member, Governing Council and Governing Body, Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital, 20192022 .
4. Member, Projects Advisory Committee (PAC) for the International Cooperation Programmes of DST in the area of Physics, Astrophysics and Laser. 2020-Present
5. Member, Governing Council, Indian Institute of Geomagnetism, Mumbai, 20202023.
6. Chairman, INSA-International Science Council Committee for COSPAR, URSI and SCOSTEP, for 2020-2023.
7. Member, Scientific Advisory Committee of National Atmospheric Research Laboratory (SAC-NARL), Gadanki, 2019-Present
8. Member, TIFR Balloon Facility Management Board, 2018-Present
9. Member, State Audit Advisory Board (SAAB) for Gujarat, 2020-2021.
10. Chief Guest, 94th Foundation Day of Andhra University, Visakhapatnam, Andhra Pradesh, 26 April 2019.
11. Guest of Honour, 16th Convocation of Dhirubhai Ambani Institute of Information and Communication Technology (DA-IICT), Gandhinagar, Jan. 18, 2020.
12. Chief Guest, 20th Foundation Day of Charotar University of Science and Technology (CHARUSAT), Changa, Gujarat, 28 Jan., 2020.
13. Chief Guest, Science Exhibition Opening Ceremony, Sheth Chimanlal Nagindas Vidyavihar, Ahmedabad, 10 August 2019.
14. Chief Guest, Inaugural Function of TECHKSHETRA, The Maharaja Sayajirao University, Baroda, 14 Feb., 2020.
15. Member, Science Organizing Committee, Ninth International Conference on Mars, California Institute of Technology (Caltech), Pasadena, California, USA, 2226 July, 2019.
16. Co-Convener, Session PS17, "Future and Current Space Missions and Instrumentation for Space and Planetary Science", AOGS 16th Annual Meeting, Singapore, 28 July - 02 August, 2019.
17. Member, Science Organizing Committee, "Planetary Exploration, Horizon 2061", 3rd Synthesis Workshop Toulouse, France, 11-13 Sept. 2019.

**S. A. Haider**

18. Session Chair, Indian Planetary Sciences Conference (IPSC) 2020, Theme: Science & Exploration of Mars & Venus

**Srubabati Goswami**

19. Invited to be member of the Editorial board for Journal of Physics G, IOP publications since January 2020.
20. Session Chair for the session Neutrinos and Non-Accelerator Probes of New Physics: Parallel 5 , July1-5 2019, Manchester, 2019.
21. Member, Scientific Advisory Committee, Neutrino Oscillation Workshop (NOW) 2020 to be held in Otranto, Italy in September 2020.
22. Co-chair, Pressing for Progress 2019: An IPA conference towards gender Equity, held in University of Hyderabad 19-21 September, 2019.

**Duggirala Pallamraju**

23. External examiner for theses submitted to i) Kerala University, ii) Andhra University, and iii) The University of the South Pacific, Republic of Fiji.
24. Member, Advisory Committee, National Conference on Space and Atmospheric Science (NCSAS-2019), School of Science, Sanjay Ghodawat University (SGU), Kolhapur, 10-11 May 2019.
25. Member, Scientific Organizing Committee, of the committee to conduct the Space weather school organized by the Center for Space Science and Technology Education in Asia and Pacific (CSSTEAP, affiliated to the United Nations) and conducted by PRL during 18-27 November 2019 at PRL

**Nandita Srivastava**

26. Member of Editorial Board, Journal of Astrophysics and Astronomy for January 2020December 2022.
27. Co-chair, Scientific organizing committee, $38^{th}$ Astronomical Society of India meeting held at IISER Tirupati, 13-17 February 2020.
28. Session Chair, Thesis presentations, $38^{th}$ Astronomical Society of India meeting held at IISER Tirupati, 13-17 February 2020.
29. Judge, Poster Session, Sun and Solar System Section, $38^{th}$ Astronomical Society of India meeting held at IISER Tirupati, 13-17 February 2020.
30. Session Chair, National Large Solar Telescope (NLST), workshop on "Ground based instrumentation for solar Astronomy" during ASI meeting, IISER, Tirupati, 13 February 2020.

31. Member, Scientific organizing committee, D2.4 Session, Sun-Heliosphere Connection Events: Origin, Propagation, Impact and Prediction,COSPAR assembly to be held in Sydney, 15-22 August 2020.
32. Member, Scientific organizing committee, E2.3 Session, Driving Solar Eruptions, COSPAR assembly to be held in Sydney, 15-22August 2020
33. Member, Scientific organizing committee, Capacity Building Workshop of COSPAR on Coronal and interplanetary shocks, 6-17 January 2020.
34. Session Chair and Course Lecturer, COSPAR capacity building workshopon Coronal and interplanetary shocks, 6-17 January 2020.
35. Co-Chair, Scientific organizing committee and Course Lecturer, "Short Course on Space Weather" organized by UN-CSSTEAP at PRL, 14-27November 2019.

**Shibu K Mathew**

36. Session Chair, Adaptive Optics and image restoration techniques, workshop on "Ground based instrumentation for solar astronomy" during ASI meeting, IISER, Tirupati, 13 February 2020.

**Varun Sheel**

37. 2018-Present: Expert in Board of Studies of Amity Institute of Applied Sciences.
38. Course Director of "Summer Training School on Planetary Science and Exploration", PRL, Ahmedabad, 01 May 30 June, 2019.
39. Convenor of a session on Mars and Venus at the 16th annual meeting of the Asia Oceania Geosciences Society (AOGS), Singapore, 28 July-02 August 2019.
40. Convenor, "1$^{st}$ Indian Planetary Science Conference (IPSC-2020)", held at PRL, 19-21, February, 2020.

**Debabrata Banerjee**

41. Session Chair, Indian Planetary Sciences Conference (IPSC) 2020, Theme: Solar System Processes, Jovian planets, Asteroids and Small bodies
42. Member, Technical Advisory Committee for Science, Technology and Innovation (STI) Policy Funds, GUJCOST.
43. Member, ISRO-DTDI Expert Committee for AI/ML Training Programme.

**Bijaya K. Sahoo**

44. Selected as a Member of Program Committee for the 27th International Conference on Atomic Physics (ICAP-27), which will be held in Toronto, Canada from 1924 July, 2020.
45. Chaired a session at the 8th Topical Conference (TC2020) on Atomic and Molecular Collisions for Plasma Applications held at Department of Physics, IIT Roorkee during 35 March, 2020.

**Dibyendu Chakrabarty**

46. Invited as External examiner for a Ph.D thesis defense at University of Mumbai in May 2019.
47. Invited to be a reviewer for the Gandhian Young Technological Innovation (GYTI-2019) Award, 2020.
48. Member of the committee to conduct the Space weather school entitled "A short course on Space weather" organized by the Center for Space Science and Technology Education in Asia and Pacific (CSSTEAP, affiliated to the United Nations) and conducted by PRL during 18-27 November 2019 at PRL.
49. Member of LOC of the PRL Alumni Association meeting at PRL on "Research at PRL: Synoptic perspective" on 24 December 2019.
50. Invited to serve as a member of the working group of the category 2.1 ("How does the thermosphere and ionosphere respond to various forcings from above and from below?") under Pillar 2 of PRESTO (PREdictability of the variable Solar-Terrestrial cOupling) which is the scientific program for SCOSTEP (Scientific Committee on Solar-Terrestrial Physics) for the five year period from 2020 - 2024.
51. Elected as a co-ordinator by the Aditya Science Working Group for the theme "Solar wind and Heliospheric Studies" under Multi-payload Science category for the Aditya-L1 mission.

**Som Kumar Sharma**

52. Member, National Organizing Committee, National Conference on Space and Atmospheric Science (NCSAS-2019), Department of Physics (Space Science), School of Science, Sanjay Ghodawat University (SGU), Kolhapur, 10-11 May 2019.
53. Served as subject expert members for the DST INSPIRE Research Project reviews at NIRMA University, 26 July 2019 Ahmedabad.
54. Main convener: Exploration and Science of the Earth's Lower and Middle Atmosphere: Past, Present and Future perspectives, 16$^{th}$ annual meeting of the Asia Oceania Geosciences Society (AOGS), 28 July-02 August 2019 Singapore.
55. Member of scientific program committee of INAC-4, panel member of judges for best paper award, co-chair of a session, ISSE National Conference (INAC-4) at Space Applications Centre, 26-27 September 2019 Ahmedabad.
56. Invited as chief guest for inaugural talk, Session Chair and Judge for the best paper in MoES sponsored conference on "Recent Advances in Anthropogenic Disaster Monitoring" (RAADM-2019) at Chennai, 22-23 October 2019.
57. Member, organizing committee, Indian Space Research Organization -Structured Training programme (ISRO-STP) on "Scientific Satellite Missions: payload definition, development and data utilization" during 22 - 28 January 2020 at SAC/PRL, Ahmedabad.
58. An expert member of the review panel of the NASA Postdoctoral Programme (NPP)-2019.

**Kuljeet K. Marhas**

59. Session Chair, Indian Planetary Sciences Conference (IPSC) 2020, Theme: Study of meteorites & terrestrial analogues.
60. Scientific Advisory Committee, Meteoritical society meeting, Japan 2019.
61. Scientific Advisory Committee, Astronomy with Radioactive Isotopes, Budapest, Hungary 2020.

**Bhuwan Joshi**

62. Felicitated by the Uttarakhand Chief Minister Mr. T. S. Rawat during the Youth Festival organized by the Hindustan Times (HT) media with active support from Government of Uttarakhand on 7 November 2019 in Almora, Uttarakhand for contributions in the field of Solar Physics and Space Sciences.

**Amitava Guharay**

63. Examiner for thesis submitted to Department of Astronomy, Osmania University, February 2020.

**Neeraj Rastogi**

64. Best poster award,"The composition of gas-and particle-phase oxidation products in a high-chlorine environment in New Delhi during the winter", European Aerosol Conference (EAC) 2019, Gothenburg, Sweden during August 25-30, 2019.
65. Session Chair, 'Variability and long-term changes of the trace gases in the ASMA' in in the International Conference "Asian Summer Monsoon Anticyclone: Gateway of Surface Pollutants to the stratosphere" at Chennai, India, February 10-11, 2020.
66. Invited Member: Editorial Advisory Board, Asian Journal of Atmospheric Environment.
67. Nodal Faculty for Gujarat, the National Clean Air Programme (NCAP), Ministry of Environment, Forest & Climate Change, 2019.

**Anil Dutt Shukla**

68. Nominated to the "High Powered Committee (HPC)" pursuant to the directions of Hon'ble Supreme Court of India's Order dated 08-08-2019 in M. A. No. 2678-2680 of 2018 in C.A. No(s), 8518-8250 of 208 and Contempt Petition No. 423 of 2019 in C.A. No. 10930 of 2018 in the matter of Citizens for Green Doon and Others Vs. Union of India & Others.
69. Nature India carried out a news article on our research work on the behavior of glacier in the Puche valley, Leh, in Ladakh Himalaya, entitled "This Himalayan glacier has been advancing, not receding", doi:10.1038/nindia.2020.1, 3 January 2020.

**Bhalamurgan Sivaraman**

70. Member of scientific advisory committee in "6th National Symposium on ShockWaves2020", PRL, 2628, February 2020.

**Veeresh Singh**

71. Invited as an external examiner for Ph.D. thesis defense at Pondicherry university Puducherry on 12 February 2020.

**Mudit K. Srivastava**

72. Chaired a Session (Instrumentation and Techniques III) in $38^{th}$ Astronomical Society of India (ASI) meeting at IISER Tirupati during 13-17 February 2020.

**Jayesh P. Pabari**

73. 2018-Present: Expert in Doctoral Admission Committee, GTU, Ahmedabad.
74. Secretariat, "$1^{st}$ Indian Planetary Science Conference (IPSC-2020)", held at PRL, 19-21, February, 2020.
75. Organizing Committee Member of Summer Training School on Planetary Science and Exploration, PRL, Ahmedabad, 01 May 30 June, 2019.

**M. Shanmugam**

76. Session Chair, Indian Planetary Sciences Conference (IPSC) 2020, Theme: Vision and Opportunities for Future Planetary Exploration.

**Amit Basu Sarbadhikari**

77. Registered reviewer of Meteoritics and Planetary Science, Wiley Publications.

**Karnnam Durga Prasad**

78. Secretariat, "$1^{st}$ Indian Planetary Science Conference (IPSC-2020)", held at PRL, 1921, February, 2020.
79. Selected and served as Programme Committee Member for COMSOL International Conference, 27-29 Nov. 2019, Bangalore.
80. Selected as Member, Gujarat Chapter, IEEE GRSS.

**Neeraj Srivastava**

81. Session Chair, Indian Planetary Sciences Conference (IPSC) 2020, Theme: Lunar Science: Present Understanding & Outstanding Questions.

**Rajesh K.Kushawaha**

82. Chaired a session at the 8th Topical Conference (TC2020) on Atomic and Molecular Collisions for Plasma Applications held at Department of Physics, IIT Roorkee during 35 March, 2020.

**Naveen Chauhan**

83. Invited as a resource person in first National Symposium on Luminescence Dating Methods and Protocols in Birbal Sahani Institute for Palaeosciences (BSIP), Lucknow, held during March 29-30, 2019. Discussion led to formation of group "Indian Association for Luminescence Dating (IALD).
84. Invited as a resource person in 5-day National workshop on "Luminescence Dating: Methodology and Application held in NGRI, Hyderabad during December 711, 2019.

**Rohan E. Louis**

85. Session Chair, Sun and Solar System Session-I, $38^{th}$ Astronomical Society of India meeting held at IISER Tirupati during 13-17 February 2020.

**P. Kalyan S. Reddy**

86. Best Paper Award by Popular Vote for our Poster Paper titled A 3D Surface Thermophysical Model for Mars Implications for Mars Landing Missions" by P. Kalyana Srinivasa Reddy, Chandan Kumar, K. Durga Prasad and Varun Sheel, COMSOL International Conference, 27-29 Nov. 2019, Bangalore.

**Research Scholars**

**Prabir K. Mitra**

87. $1^{st}$ prize at the $31^{st}$ Research Methodology Workshop on Physics & Electronics, Gujarat University, Ahmedabad, 21 November, 2019 for the poster entitled "Solar Physics: Importance, Current Understanding and Yet Unanswered Problems".

**Ranadeep Sarkar**

88. Research paper on "Lorentz Force Evolution Reveals the Energy Build-up Processes during Recurrent Eruptive Solar Flares" is featured on RHESSI Science Nugget (No. 364).
89. Research paper on "Evolution of the Coronal Cavity From the Quiescent to Eruptive Phase Associated with Coronal Mass Ejection" is featured on the AAS Nova website and highlighted as news in PROBA2 Science Center.

**Arijit Roy**

90. Americal Chemical Society Best Poster Prize for the poster "Shock Processing of Carbon Nanopowder in 3rd National Conference on Chemistry, held at IIT Gandhinagar on 12-13 February 2020.

**Scientific & Technical Staff in administration**

**Sneha Nair**

91. Secured $4^{th}$ position in the Memory Competition organized by Space Applications Centre, Ahmedabad.

# Human Resource Development

**Human Resource Development at PRL** The laboratory has a strong Human Resource Development (HRD) component with Doctoral, Post-Doctoral, 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 organizes intensive summer programmes for students as well as college teachers every year. The purpose is to provide them an insight into current research activities being pursued at PRL which they can continue even after returning back to their colleges. It is also aimed at motivating them to take up research in basic sciences. Brief details of scientific output and staff details in numbers during the reporting year are reported here.

**Research 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 students in experimental and theoretical physics. With this in view, PRL offers a graduate programme through Research Fellowship leading to Ph. D. degree. It also provides opportunities for carrying out post-doctoral research. The strength of fellows under these programmes are presented in figure 1.

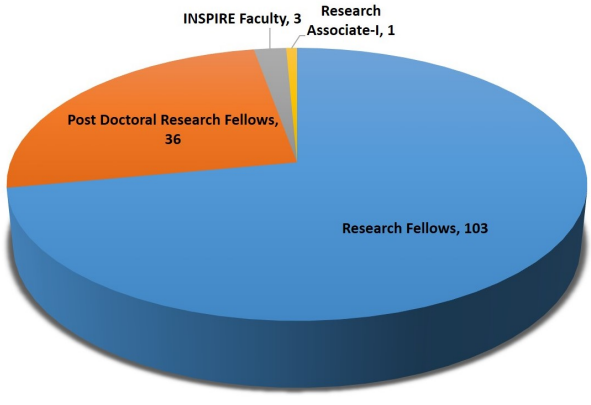



Figure 1: Research Programmes.

**Training Opportunities** PRL provides summer training programme to students doing their Bachlor's and Master's degree in Physics, Chemistry, Earth Sciences to acquaint them with the research programmes and opportunities available at PRL. This includes the internship of students selected through three national science academies and Indian Institute of Space Science and Technology, Thiruvananthapuram.

PRL also 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.

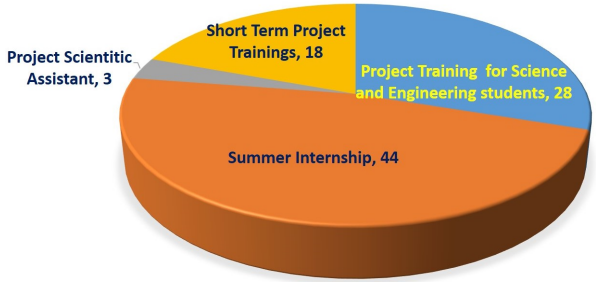



Figure 2: Internship Training Programmes.

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

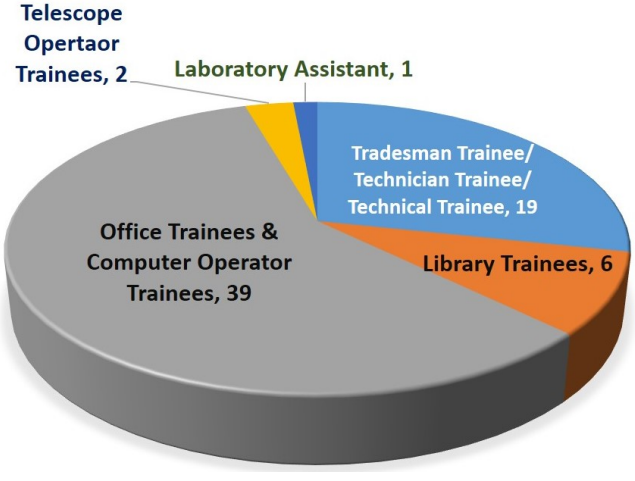



Figure 3: Training Programmes in technical and administrative areas.

**Research Contributions** The research work carried out by PRL scientists are published in reputed and peer reviewed national and international journals. Few 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 attend 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 chairmen and members of scientific committees for organizing national conferences and symposia. They are also invited to convene and chair sessions during symposia and meetings. The research output during the reporting year are shown in figure 4.

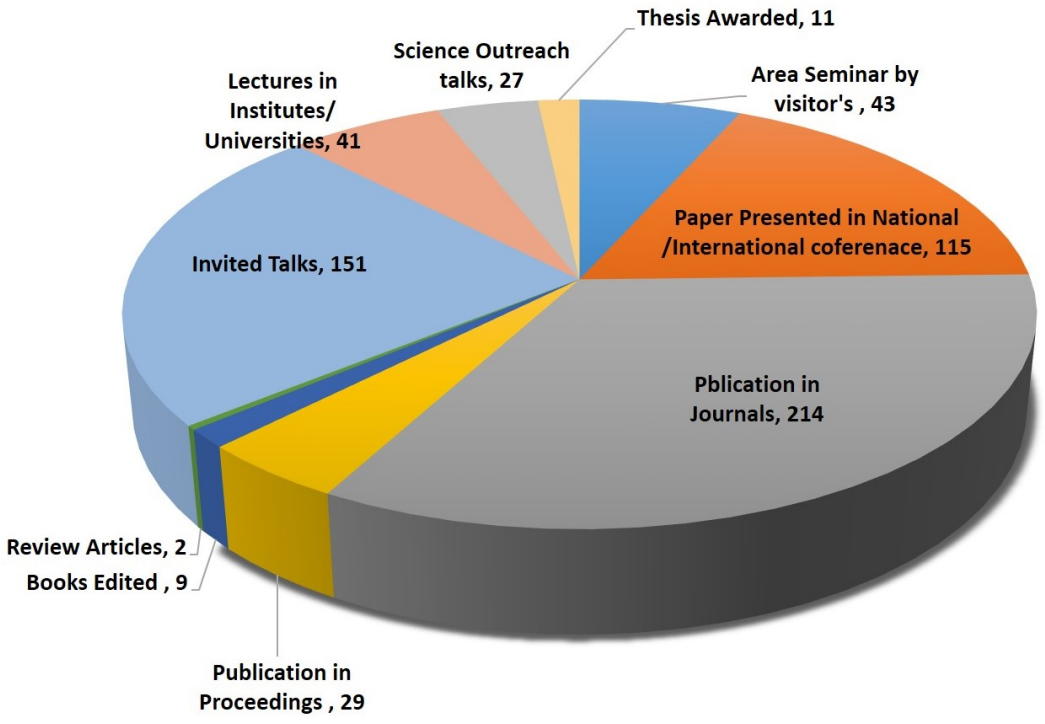



Figure 4: Research Contributions.

**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 plays a pivotal 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 are shown in figure 5.

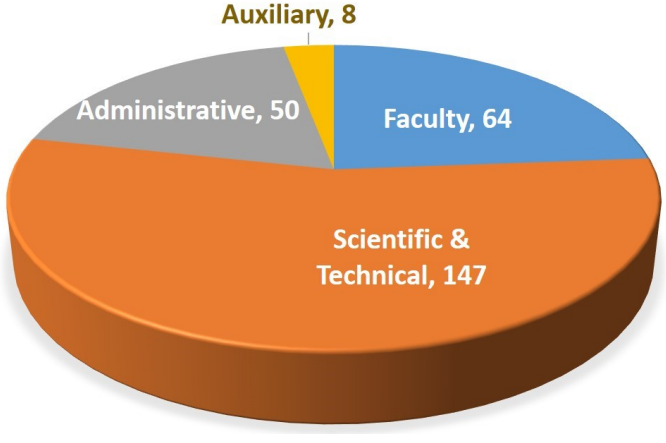



Figure 5: The distribution of PRL staff.

**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 450 research scholars have completed their Ph.D. 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 need 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 are registering 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 2019 20 JRFs have joined PRL and 11 SRFs have been awarded Ph.D. degree.

Following is a list of courses offered to Junior Research Fellows of the 2019 batch. Each course is of four credits and 40 hours of teaching.

**Semester 1 courses**

1. RS – 601 Research Methodology (Error Analysis and Numerical Methods) [Instructors: Prof. Varun Sheel & Dr. Arvind Singh]
2. AA-603 Stellar Photosphere – [Instructor: Prof. Abhijit Chakraborty]
3. AMO 602 - Light-matter interaction [Instructors: Prof. R P Singh, B K Sahoo]
4. AMO 603 - Experimental techniques in Atomic, Molecular, and Optical Physics [Instructors: Dr. G.K. Samanta & Dr. Naveen Chauhan]
5. PS 602 - Exploration of Solar System [Instructors: Prof. D. Banerjee & Mr. R. Mahajan]
6. PS 603 - Atmospheres & Environments of Planetary Objects [Instructors: Prof. V Sheel & Dr. K Acharyya]
7. PS 604 - Fundamentals of Remote Sensing (elective) [Instructors: Drs. S. Vijayan & Neeraj Srivastava]
8. TH 602 Advanced Quantum Mechanics and Quantum Field Theory [Instructor: Dr. Ketan Patel]
9. TH 603 Statistical Mechanics [Instructor: Prof. D. Angom]
10. TH 604 Advanced topics on electrodynamics [Instructor: Prof. J R Bhatt]
11. SA 602 Introduction to Space and Atmospheric Physics - [Instructors: Prof. D. Pallamraju & Dr. N. Ojha]
12. SA 603 Techniques for Space and atmospheric studies - [Instructors: Drs. RP Singh & Rajesh T A]
13. SA 604 Space Plasma Physics (elective) - [Instructor: Dr. D. Chakrabarty]
14. ES 602 - Isotope Geology [Instructor: Prof. J. S. Ray]
15. ES 603 - Earth Surface Processes [Instructor: Dr. A. D. Shukla]
16. ES 604 - Global Change: Perspectives on Water and Climate (elective) [Instructors: Dr. R. D. Deshpande & Dr. Sanjeev Kumar]
17. RS – 601 Research Methodology - [Instructors: Dr. Girjesh Gupta (offered at USO for JRFs selected to work at Udaipur]
18. SP – 602 Introduction to Solar Physics - [Instructor: Dr. Brajesh Kumar]
19. SP – 603 Fundamentals of Astrophysics - [Instructor: Dr. Bhuwan Joshi]
20. SP – 604 Electrodynamics - [Instructor: Dr. Ramit Bhattacharyya]

**Semester 2 courses:**

1. AMO 701 Ultrafast Physics - [Instructors: Dr. Rajesh Kushawaha]
2. AMO 702 Astrochemistry - [Instructors: Dr. B. Sivaraman]
3. AMO 703 Quantum Optics and Quantum Information - [Instructors: Prof. R.P. Singh]
4. AMO 704 Lab Techniques in Atomic, Molecular and Optical Physics - [Instructors: Dr. G. K. Samanta]
5. SA 701 Upper Atmospheric Physics - [Instructors: Prof. D. Pallamraju & Dr. Ravindra P. Singh]
6. SA 702 Middle Atmospheric Physics - [Instructors: Dr. Som Kumar Sharma & Dr. Amitava Guharay]
7. SA 703 Lower Atmospheric Physics - [Instructors: Dr. Lokesh Kumar Sahu & Dr. Harish Gadhavi]
8. ES 701- Paleoclimate Studies - [Instructors: M.G. Yadav & R. Bhushan]
9. ES 702 Ocean and Atmospheric Chemistry - [Instructors: Drs. V. Goswami & A. K. Sudheer]
10. ES 703 Stable Isotope in Nature - [Instructors: Dr. Amzad H Laskar]
11. PS703 - Planetary Atmospheres - [Instructors: Drs. Jayesh Pabari, K. Durga Prasad & S. K. Mishra]
12. PS704 - Cosmochemistry and Planetary Geochemistry and Geology - [Instructors: Drs. Dwijesh Ray, Amit Basu Sarbadhikari & Dipak K. Panda]
13. PS705 - Planetary Surface Science through Remote Sensing - [Instructors: Drs. Vijayan S. & Megha Upendra Bhat]
14. TH 701 Quantum Field Theory - II - [Instructor: Prof. Namit Mahajan]
15. TH 702 Particle Physics : - [Instructor: Dr. Partha Konar]
16. TH 703 Advanced Condensed Matter Physics : - [Instructor: Dr. Navinder Singh]
17. AA 701 Star Formation and Stellar Astrophysics - [Instructors: Drs. Lokesh Dewangan & Arvind Rajpurohit]
18. AA 702 Galactic and Extragalactic Astronomy - [Instructors: Prof. S. Naik & Dr. Veeresh Singh]
19. AA 703 Instrumentation & Techniques - [Instructor: Dr. Mudit Srivastava]
20. SP 701 MHD processes in solar atmosphere - [Instructors: Drs. Ramitendranath Bhattacharyya & Bhuwan Joshi]
21. SP 702 Coronal and heliospheric processes - [Instructors: Prof. Nandita Srivastava & Dr. Girjesh Gupta]
22. SP 703 Instrumentation and diagnostic techniques - [Instructors: Drs. Rohan Eugene Louis & A. Raja Bayanna]

The list of projects done by JRFs of 2019 batch as a part of their course work is given as follows:

**Bharathiganesh D**

1. “Ginzburg Landau Theory for Surface Superconductivity”, Semester 2 Project, from January 2020 to May 2020, [Supervisor: Prof. Navinder Singh, Division: Theoretical Physics].
2. “Effects of Boundary Curvature and Bulk in Surface Superconductivity”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Prof. Navinder Singh, Division: Theoretical Physics].
3. “ Atmospheric Aerosols ”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. T A Rajesh, Division: Space and Atmospheric Sciences].
4. “ An Introduction to the General Theory of Relativity ”, Semester 2 Project, from August 2019 to December 2019, [Supervisor: Prof. Namit Mahajan, Division: Theoretical Physics].

**Bijoy Dalal**

5. “ An investigation of magnetospheric substorms”, Semester 2 Project, from January 2020 to May 2020, [Supervisor: Dr. Dibyendu Chakrabarty, Division: Space and Atmospheric Sciences].
6. “ Astrophysical shocks and particle acceleration”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Dibyendu Chakrabarty, Division: Space and Atmospheric Sciences].
7. “ Study of interaction of high energetic particles with semi-conductor detectors ”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Prof. Santosh V. Vadawale, Division: Space and Atmospheric Sciences].
8. “Elementary data analysis in MATLAB”, Semester 2 Project, from August 2019 to December 2019, [Supervisor: Prof. Lokesh Kumar Sahu, Division: Space and Atmospheric Sciences].

**Birendra Chhotaray**

9. “Thermonuclear Burst”, Semester 2 Project, January 2020 to May 2020, [Supervisor: Prof. Sachindra Naik, Division: Astronomy & Astrophysics].
10. “Study of Cataclysmic Variables”, Summer Semester Project 1, May 2020 to July 2020, [Supervisor: Dr. Vishal Joshi, Division: Astronomy & Astrophysics].
11. “Multiwavelength Studies of Solar Flares”, Summer Semester Project 1, May 2020 to July 2020, [Supervisor: Dr. Bhuwan Joshi, Division: Solar Physics].
12. “Stellar Evolution”, Semester 2 Project, August 2019 to December 2019, [Supervisor: Prof. Sachindra Naik, Division: Astronomy & Astrophysics].

**Gourav Mitra**

13. “ Study of seasonal variability of long-period planetary waves ”, Semester 2 Project, from January 2020 to May 2020, [Supervisor: Dr. Amitava Guharay, Division: Space and Atmospheric Sciences].
14. “ Characteristics of summertime atmospheric tides in the MLT over Cachoirrea Paulista”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Amitava Guharay, Division: Space and Atmospheric Sciences].
15. “ Perturbation analysis of atmospheric waves ”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Aveek Sarkar, Division: Astronomy & Astrophysics].
16. “ Derivative Techniques for Diagnosing the Atmospheric Boundary Layer Height using Ceilometer Lidar Observation ”, Semester 2 Project, from August 2019 to December 2019, [Supervisor: Dr. Som Kumar Sharma, Division: Space and Atmospheric Sciences].

**Jibanjyoti Routray**

17. “Geochemical evidences regarding age, source and origin of Panjal trap”, Semester 2 Project, from January 2020 to April 2020, [Supervisor: Dr. J S RAY, Division: Geosciences].
18. “ X-ray diffraction study of Carbonaceous chondrite”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. J S ray, Division: Geosciences].
19. “ A brief study on meteorites, its classification and organic matters present in it ”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Anil D Shukla, Division: Planetary sciences].
20. “ Geochemical Study of a Chilika Lake ”, Semester 2 Project, from August 2019 to November 2019, [Supervisor: Dr. Sanjeev Kumar, Division: Geosciences].

**Kimi Khungree Basumatary**

21. “ Petrochemical constraints on target rocks and impactite in Lonar impact crater,”, Semester 2 Project, from January 2020 to May 2020, [Supervisor: Dr. Dwijesh Ray , Division: Planetary Sciences].
22. “ Morphology and Spectral study of Copernican age crater in South Pole Aitken basin ”, Summer Semester Project 1, from June2020 to July 2020, [Supervisor: Dr. Vijayan S, Division: Planetary Sciences].
23. “ X-ray diffraction study of Carbonaceous chondrite ”, Summer Semester Project 1, from June 2020 to July 2020, [Supervisor: Dr. A. D Shukla, Division: Geosciences].
24. “ Lineament Mapping of the Western part of Orientale Basin ”, Semester 2 Project, from August 2019 to December 2019, [Supervisor: Dr. Neeraj Srivastava, Division: Planetary Sciences].

**Kshitiz Upadhyay**

25. “ Photometry for Measurement of Daytime Optical Airglow Emissions ”, Semester Project, from January 2020 to May 2020, [Supervisor: Prof. D Pallamraju, Division: Space and Atmospheric Sciences].
26. “ Geomagnetic Storm and Its Consequences”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Prof. D Pallamraju, Division: Space and Atmospheric Sciences].

27. " Polarized Views of Astronomical Objects by Optical Polarimeter ", Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Shashikiran Ganesh, Division: Astronomy & Astrophysics].
28. " Atmospheric composition over India: model simulation", Semester 2 Project, from August 2019 to December 2019, [Supervisor: Dr. Narendra Ojha, Division: Space and Atmospheric Sciences].

**Km Ajayeta Rathi**

29. "Evidence of Anthropogenic activities through Black Carbon estimate in lake sediments ", Semester 2 Project, from January 2020 to April 2020, [Supervisor: Dr. Sanjeev Kumar, Division: Geosciences].
30. " Harappan Sites in Gujarat (India) ", Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. J S ray, Division: Geosciences].
31. " South Asian Monsoon (Indian Monsoon) ", Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Narendra Ojha, Division: Space and Atmospheric Sciences].
32. " Time Series analysis of microbial abundance over the Atlantic Ocean ", Semester 2 Project, from August 2019 to November 2019, [Supervisor: Dr. Arvind Singh, Division: Geosciences].

**Neha Panwar**

33. " Lunar Magma Ocean", Semester 2 Project, from January 2020 to May 2020, [Supervisor: Dr. Neeraj Srivastava, Division: Planetary Sciences].
34. " Lunar Mg-suite of rocks ", Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Neeraj Srivastava, Division: Planetary Sciences].
35. " Iron Isotope Systematics for Understanding the origin on Banded Iron Formation ", Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. A. D. Shukla, Division: Geosciences].
36. " Glaciation on Mars as observed on Renaudot Crater ", Semester 2 Project, from September 2019 to December 2019, [Supervisor: Dr. Vijayan S , Division: Planetary Sciences].

**Sandipan Borthakur**

37. "A Brief Study on the Evolution of Star Cluster: NGC2323", Semester 2 project, from January 2020 to May 2020, [Supervisor: Dr. Manash Samal, Division: Astronomy & Astrophysics].
38. "To Determine Mass and Metallicity of the probable AGB star contributing to a sample of Presolar grain", Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Kuljeet Kaur Marhas, Division: Planetary Science].
39. "Effects of Galactic disk on the star cluster NGC6397: A Qualitative Study ", Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Manash Samal, Division: Astronomy & Astrophysics].
40. "Casini Mission: Its instrumentation ", Semester 2 Project, from August 2019 to December 2019, [Supervisor: Dr. Shashikiran Ganesh, Division: Astronomy & Astrophysics].

**Santunu Kumar Panda**

41. "Study of FT-IR Spectrometer (Fourier Transformed Infrared Spectrometer", Semester 2 Project, from February 2020 to May 2020, [Supervisor: Dr. B. Sivaraman, Division: Atomic Molecular and Optical Physics].
42. "Application of radiogenic isotopes (87Sr/86Sr, $\varepsilon$Nd) in provenance studies, Summer Semester Project 1, from June 2020 to July 2020, [Supervisor: Dr. Vineet Goswami, Division: Geosciences].
43. "Effects on CW-OSL components of quartz as a result of irradiation, stimulation and annealing", Summer Semester Project 1, from June 2020 to June 2020, [Supervisor: Dr. Naveen Chauhan, Division: Atomic Molecular and Optical Physics].
44. "Luminescence Mechanism in solids, its instrumentation and Application", Semester 2 Project, from August 2019 to December 2019, [Supervisor: Dr. Naveen Chauhan, Division: Atomic Molecular and Optical Physics].

**Satyam Agarwal**

45. " Physical properties of magnetically closed loops observed in the solar corona ", Semester 2 Project, from January 2020 to May 2020, [Supervisor: Dr. Girjesh R Gupta, Division: Solar Physics].
46. " Magnetic null points", Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Ramitendranath Bhattacharyya, Division: Solar Physics].
47. " Solar and Interplanetary causes of geomagnetic storms ", Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Dibyendu Chakrabarty, Division: Space and Atmospheric Science].
48. " Fourier Transform and its Application to Solar Observational Data ", Semester 2 Project, from August 2019 to December 2019, [Supervisor: Dr. Brajesh Kumar, Division: Solar Physics].

**Saumya Jyoti Sarkar**

49. "On optical dichroism and chirality measurement", Semester 2 Project, from March 2020 to July 2020, [Supervisor: Goutam K Samanta, Division: Atomic Molecular and Optical Physics].
50. "Role of High-Dimensional Entanglement in Quantum Communication", Summer Semester Project 1, from June 2020 to July 2020, [Supervisor: R. P. Singh, Division: Atomic Molecular and Optical Physics].
51. "Quantum Hall effect", Summer Semester Project 1, from June 2020 to July 2020, [Supervisor: Prof. Angom Dilip Kumar Singh, Division: Theoretical Physics].
52. "Coincidence imaging to explore quantum entanglement", Semester 2 Project, from September 2019 to December 2019, [Supervisor: Goutam K Samanta, Division: Atomic Molecular and Optical Physics].

**Saurabh Kumar**

53. “Renormalization”, Semester 2 Project, from January 2020 to April 2020, [Supervisor: Dr. Namit Mahajan, Division: Theoretical Physics].
54. “ Beta function in Non-Abelian Gauge Theories”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Satyajit Seth, Division: Theoretical Physics].
55. “ Understanding Climate Change and Its Consequences ”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Vineet Goswami, Division: Geosciences].
56. “ Supersymmetric Charges and Their Algebra ”, Semester 2 Project, from August 2019 to December 2019, [Supervisor: Dr. Ketan Patel, Division: Theoretical Physics].

**Sreekantham Kumar Rithvik**

57. “Understanding MELVIN”, Semester 2 Project, from March 2020 to July 2020, [Supervisor: Prof R.P. Singh, Division: Atomic Molecular and Optical Physics].
58. “Understanding the AI Physicist Learning Agent”, Summer Semester Project 1, from June 2020 to July 2020, [Supervisor: Dr Partha Konar, Division: Theoretical Physics].
59. “Calculating the reduced polarizabilities for Cs atom irradiated by a LASER”, Summer Semester Project 1, from June 2020 to July 2020, [Supervisor: Dr Bijaya Kumar Sahoo , Division: Atomic Molecular and Optical Physics ].
60. “ Evolving Maximally Entangled States using Genetic Algorithms ”, Semester 2 Project, from August 2019 to November 2019, [Supervisor: Prof R.P. Singh, Division: Atomic Molecular and Optical Physics].

**Swagatika Chakra**

61. “Isotopic Characterization of Groundwater in Madhya Pradesh to identify vulnerability to depletion”, Semester 2 Project, from January 2020 to April 2020, [Supervisor: Dr. R.D. Deshpande, Division: Geosciences].
62. “ Hydrological Indicators as revealer of Local Meteorological Processes”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. J S ray, Division: Geosciences].
63. “ Evapotranspiration ”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. VIjayan S, Division: Planetary science].
64. “ K-Pg Mass Extinction”, Semester 2 Project, from August 2019 to November 2019, [Supervisor: Prof. J. S. Ray, Division: Geosciences].

**Tanya Sharma**

65. “Security Analysis of BB84 Protocol”, Semester 2 Project, from February 2020 to May 2020, [Supervisor: Prof. R.P. Singh, Division: Atomic Molecular and Optical Physics].
66. “ Quantum Entanglement ”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Prof. G.K. Samanta, Division: Atomic Molecular and Optical Physics].
67. “ Density Operator ”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Ketan M. Patel, Division: Theoretical Physics].
68. “ Application of BB84 in Quantum Cryptography ”, Semester 2 Project, from August 2019 to November 2019, [Supervisor: Prof. R. P. Singh, Division: Atomic Molecular and Optical Physics].

**Vardaan Mongia**

69. “Quantum Algorithms”, Semester 2 Project, from January 2020 to April 2020, [Supervisor: Prof. GS Samanta, Division: Atomic Molecular and Optical Physics].
70. “Quasi 1-D Bose Einstein Condensates in Weakly Interacting Regime”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Prof. Angom D.K. Singh, Division: Theoretical Physics].
71. “Quantum Random Number Generators (QRNGs)”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Prof. R.P. Singh, Division: Atomic Molecular and Optical Physics].
72. “ Public Key Distribution to Quantum Key Distribution”, Semester 2 Project, from July 2019 to December 2019, [Supervisor: Prof. G.S. Samanta, Division: Atomic Molecular and Optical Physics].

**Vineet Rawat**

73. “ Control of polarimeter using RPi with real-time application & Polarization study of Post-AGB stars”, Semester 2 project, from January 2020 to May 2020, [Supervisor: Dr. Shashikiran Ganesh, Division: Astronomy & Astrophysics].
74. “ Deep near-infrared imaging of embedded cluster Haffner18: constraints on stellar properties and initial mass function. Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Manash Ranjan Samal, Division: Astronomy & Astrophysics].
75. “ Star formation in galaxies along the Hubble sequence ”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Kinsuk Acharyya, Division: Planetary Science].
76. “ Triggered star formation at the borders of the Galactic H II region SH2-252 ”, Semester 2 Project, from August 2019 to December 2019, [Supervisor: Dr. Manash Ranjan Samal, Division: Astronomy & Astrophysics].

**Yogesh Kumar Maurya**

77. “ Effect of dust in Martian atmosphere”, Semester 2 Project, from January 2020 to May 2020, [Supervisor: Prof. Varun Sheel, Division: Planetary Science].
78. “ Charging and Discharging of Spacecraft ”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Sanjay K. Mishra, Division: Planetary Science].
79. “ Coronal mass ejections and its space weather manifestations ”, Summer Semester Project 1, from May 2020 to July 2020, [Supervisor: Dr. Bhuwan Joshi, Division: Solar Physics].
80. “ The formation of Solar system ”, Semester 2 Project, from August 2019 to December 2019, [Supervisor: Dr. Kinsuk Acharyya , Division: Planetary Science].

# Ph.D. Awarded

**[PRL students/project associates/employees]**

**T. A. Rajesh**

1. “Spatio-temporal variations in aerosol properties over western India”, Sardar Patel University, Vallabh Vidyanagar, Anand, June, 2019. [Supervisor: Dr. S. Ramachandran, Division: Space & Atmospheric Sciences]

**Kumar Venkataramani**

2. “Optical Spectroscopic Studies of Minor Bodies of the Solar System”, Indian Institute of Technology Gandhinagar, Gandhinagar, June, 2019. [Supervisor: Dr. Shashikiran Ganesh, Division: Astronomy & Astrophysics]

**Pragya Pandey**

3. “The Growth of GIS and Remote Sensing Research Publications of Indian Scientists during the period 1991 to 2014 : A bibliometric study”, Sardar Patel University, Aug, 2019. [Supervisor: Dr. Urmila A. Thaker (Sardar Patel University, V V Nagar), Division: Library & Information Science]

**K. N. Vishnudath**

4. “Some aspects of low-scale seesaw models”, Indian Institute of Technology, Gandhinagar, October, 2019. [Supervisor: Dr. Srubabati Goswami, Division: Theoretical Physics]

**R. V. Satish Kumar**

5. “Characteristics of Brown Carbon Present in Ambient Aerosols Over Different Regions in India”, Mohanlal Sukhadia University, Udaipur, November, 2019. [Supervisor: Dr. Neeraj Rastogi, Division: Geosciences]

**Ashimananda Modak**

6. “The ion-neutral structure of the lower atmosphere of Mars”, Mohanlal Sukhadia University, Udaipur, December, 2019. [Supervisor: Dr. Varun Sheel, Division: Planetary Sciences]

**Varun Sharma**

7. “Structured beam optical parametric oscillators”, IIT Gandhinagar, December, 2019. [Supervisor: Dr. Goutam K.Samanta, Division: Atomic, Molecular and Optical Physics]

**Bhavesh Chauhan**

8. “Test of New Physics at Neutrino Telescopes”, Indian Institute of Technology, Gandhinagar, January, 2020. [Supervisor: Dr. Subhendra Mohanty, Division: Theoretical Physics]

**Bharti Kindra**

9. “(Semi) Leptonic rare decays of B mesons as probes of the Standard model and beyond”, Indian Institute of Technology, Gandhinagar, January, 2020. [Supervisor: Dr. Namit Mahajan, Division: Theoretical Physics]

**Aman Abhishek**

10. “Matter under extreme conditions and transport coefficients of hot and dense matter”, Indian Institute of Technology, Gandhinagar, January, 2020. [Supervisor: Dr. Hiranmaya Mishra, Division: Theoretical Physics]

**Nijil C Lal**

11. “Twisted Single Photons and Their Applications in Quantum Information Processing”, IIT Gandhinagar, March, 2020. [Supervisor: Dr. R. P. Singh, Division: Atomic, Molecular and Optical Physics]

# Colloquia/Public Lectures by Visitors

**Colloquium at Physical Research Laboratory, Ahmedabad**

**1. Dr. Dipankar Saha**
Central Ground Water Board, Ministry of Jal Shakti, New Delhi
***Groundwater - A critical but stressed Natural Resource in India, 15 May 2019***

**2. Prof. Ramesh P Singh**
School of Life and Environmental Sciences, Chapman University, California, USA
***An Overview of Ground, In-Situ, and Satellite Observations to Understand Land-Ocean-Atmosphere coupling associated with the Natural Hazards, 08 May 2019***

**3. Prof. Sivarani Thirupathi**
Indian Institute of Astrophysics (IIA), Bangalore, India
***Special Colloquium, Thirty meter telescope (TMT): An overview of the science and instrumentation program, 11 June 2019***

**4. Dr. Sachin Gunthe**
Indian Institute of Technology Madras, Chennai
***Atmospheric Aerosols in Indian Perspective: Climate and Ecosystem Health Implications, 24 July 2019***

**5. Prof. Mahan Mj**
School of Mathematics, Tata Institute of Fundamental Research (TIFR), Mumbai
***Hyperbolic Geometry and Chaos in the Complex Plane, 21 August 2019***

**6. Prof. Dipankar Banerjee**
Indian Institute of Astrophysics, Bengaluru
***Long Term Study of the Sun Using Kodaikanal Digitized Data, 19 September 2019***

**7. Dr Umesh Kadhane**
Indian Institute of Space and Technology, Thiruvananthapuram
***Understanding radiation tolerance of PAHs in space and role of collective excitation, 18 September 2019***

**8. Dr. Alberto Sainz Dalda**
Bay Area Environmental Research Institute, CA USA
***IRIS2: using representative profiles to invert IRIS Mg II h & kline, 31 October 2019***

**9. Dr. Haranath Ghosh**
Scientific Officer, Human Resources Development Section, Raja Ramanna Centre for Advanced Technology (RRCAT), Indore ; Faculty at Homi Bhabha National Institute (HBNI), Mumbai
***High temperature Superconductivity in Fe-based materials; role of electronic structure studies, 04 December 2019***

**10. Prof. Aditi Sen De**
Professor H, Harish-Chandra Research Institute, Allahabad
***Quantum Communication Network, 11 February 2020***

**11. Prof. Dawn Sumner**
Earth & Planetary Sciences, University of California Davis, W.M. Keck, Center for Active Visualization in the Earth Sciences
***Collaboratively Searching for Something that Might Not Exist: Life on Mars?, 11 March 2020***

**Colloquium at Udaipur Solar Observatory, Udaipur**

**1. Dr. Piyali Chatterjee**
Indian Institute of Astrophysics, Bangalore
***Solar flares from delta sunspots: Insights from a simulation, 22 April 2019***

**2. Dr. Dipankar Banerjee**
Indian Institute of Astrophysics, Bangalore
***Long term study of the Sun using Kodaikanal Digitized data, 19 September 2019***

**3. Dr. Alberto SainzDalda**
Bay Area Environmental Research Institute, CA, USA
***IRIS2: using representative profiles to invert IRIS Mg II h & kline, 31 October 2019***

**Public Lectures**

**1. Dr. Anil Bhardwaj**
Public Lecture, Physical Research Laboratory, Ahmedabad
***Indian Planetary and Space Missions, 24 September 2019***

**2. Prof. Adya Arie**
Public Lecture, Tel Aviv University, Israel
***Mixing and shaping of light beams, 25 September 2019***

**$2^{nd}$ PRL-IAPT Dr. Vikram Sarabhai Lecture**

**1. Dr R D Deshpande**
Physical Research Laboratory, Ahmedabad
***Water Resources of India: Challenges and Solutions, 27 January 2020***

# Conference/Symposium/Workshop organized by PRL

**Solar Physics**

1. “Ground-based instrumentation for solar astronomy ”, one-day workshop during $38^{th}$ meeting of the Astronomical Society of India, IISER, Tirupati on 13 February, 2020..

**Planetary Sciences**

2. “$1^{st}$ Summer Training School on Planetary Sciences & Exploration (STSPSE-2019)”, PRL, 01 May 30 June 2019.
3. “$1^{st}$ Indian Planetary Science Conference (IPSC-2020)”, PRL, 19-21, February, 2020.

**Space and Atmospheric Sciences**

4. “Short Course on the Space weather”, school organized by the Center for Space Science and Technology Education in Asia and Pacific (CSSTEAP, affiliated to the United Nations) and conducted by PRL during November 18-27, 2019 at PRL.

**Atomic, Molecular and Optical Physics**

5. “SCOPthe Students conference in optics and photonics”, SCOPthe Students conference in optics and photonics, PRL Ahmedabad, 2426 September 2019..

# Invited Talks at Conference / Symposia / Workshops

**Astronomy and Astrophysics**

**Abhijit Chakraborty**

1. "Design and development of high resolution stabilized spectrograph for TMT (30m Telescope) or extremely large telescopes", I-TMT Science and Instruments Workshop, Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital., 17-19 Oct, 2019.
2. "The Radial velocity technique for Detecting and Characterizing Exoplanets around stars: Advantages and Limitations", Workshop on Astrophysics and Planetary Science, The Israel Academy of Sciences, Jerusalem, Israel, 2-3 Dec, 2019.

**Aravind K**

3. "Contrasting behaviour of two Jupiter family comets", $38^{th}$ Astronomical Society of India Meeting, IISER, Tirupati, 13-17 Feb, 2020.

**Archita Rai**

4. "Polarization study of Lynds' Dark Nebulae", International Conference on Infrared Astronomy and Astrophysical Dust (IRAAD-2019), Inter-University Centre For Astronomy and Astrophysics (IUCAA), Pune, 22-25 Oct, 2019.

**Arvind S. Rajpurohit**

5. "PRL facilities and M dwarfs stellar parameters and Chemical abundances", 150 years of periodic table, Indian Institute of Astrophysics (IIA), Banguluru, 16-19 Nov, 2019.

**Aveek Sarkar**

6. "Towards understanding the Heliosphere-some challenges and efforts", $5^{th}$ Asia Pacific Solar Physics Meeting, Inter-University Centre For Astronomy and Astrophysics (IUCAA), Pune, 3-7 Feb, 2020.
7. "Solar wind and heliosphere : In-situ particle detectors and solar wind properties", Solar Physics Summer School, Indian Institute of Astrophysics, Leh, 10-16 June, 2019.
8. "Radiative transfer", Science of the star in our backyard: introduction and data analysis, Sulthan Bathery, Wayanad, Kerala, 26-29 Dec, 2019.

**L. K. Dewangan**

9. "Probing the birth of most massive stars", PRL Alumni meeting, PRL, Ahmedabad, 24 dec, 2019.

**Mithun N. P. S.**

10. "Probing the High Energy Emission Mechanism of Rotation Powered Pulsars with X-ray Polarimetry", Workshop on Broadband X-ray Polarization of Compact Objects $38^{th}$ Annual Meeting of Astronomical Society of India, IISER, Tirupati, 13-17 Feb 2020.
11. "X-ray Detectors for Future Astronomy Missions", Recent Trends in the Study of Compact Objects: Theory and Observation (RETCO-IV), IUCAA, Pune, 17-20 April 2019.
12. "X-ray Spectroscopy of the Sun with Chandrayaan-2 Solar X-ray Monitor (XSM): Initial Results and Prospects", $38^{th}$ Annual Meeting of ASI, IISER, Tirupati, 13-17 Feb 2020.

**Mudit K. Srivastava**

13. "Faint Object Spectrograph and Camera (FOSC) Instrumentation for PRL Telescopes: Now and the Future", India I-TMT Science and Instruments Workshop, Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital, 17-19 Oct, 2019.
14. "Ground Based Observational Facilities and Instrumentation of PRL Astronomy Division", Workshop on Science with Subaru : An Indian Perspective Science with Subaru : An Indian Perspective Workshop, TIFR, Mumbai, 18-20 Dec, 2019.
15. "Development of Faint Object Spectrograph and Camera (FOSC) Instrumentation for PRL Telescopes", $38^{th}$ Astronomical Society of India (ASI) meeting, IISER, Tirupati, 13-17 Feb, 2020.

**Manash Ranjan Samal**

16. "Understanding the formation and evolution of young massive clusters with TMT", I-TMT Science and Instruments Workshop, ARIES, Nainital, 17-19 Oct, 2019.
17. "Insights into the structure of Galactic molecular clouds and star formation within them with the study of bipolar HII regions", $38^{th}$ Annual Meeting of the Astronomical Society of India (ASI), IISER, Tirupati, 13-17 Feb 2020.

**Prachi Prajapati**

18. “Investigating Particle Acceleration in the Wolf-Rayet Bubble G2.4+1.4”, $38^{th}$ Astronomical Society of India Meeting, IISER, Tirupati, 13-17 Feb 2020.

**Prithish Halder**

19. “Computational challenges in modelling the morphologically complex dust particles”, International Conference on Infrared Astronomy and Astrophysical Dust (IRAAD-2019), Inter-University Centre For Astronomy and Astrophysics (IUCAA), Pune, 20-25 October, 2019.
20. “Dust morphology in comets and protoplanetary disks”, Planet Formation Workshop 2019, National Astronomical Observatory of Japan (NAOJ), Tokyo, Japan, 26 Nov., 2019.
21. “Study of physical properties of cosmic dust from light scattering”, $38^{th}$ Astronomical Society of India Meeting, IISER, Tirupati, 13-17 Feb 2020.

**P. Janardhan**

22. “A Declining solar polar fields, the terrestrial magnetosphere and the forthcoming solar cycle”, workshop on International Space Weather Initiative (ISWI) in collaboration with the United Nations Office of Outer Space Affairs (UNOOSA), Trieste, Italy, 20-24 May, 2019.

**Santosh Vadawale**

23. “Compton Spectro-Polarimetry For Future Indian X-ray Astronomy Mission”, Workshop on Broadband X-ray Polarization of Compact Objects, $38^{th}$ Annual Meeting of ASI, IISER, Tirupati, 13-17 March 2019.
24. “DAKSHA-On alert for high-energy transients”, Future Astronomy Missions, $38^{th}$ Annual Meeting of ASI, IISER, Tirupati, 13-17 March 2019.
25. “Science Observations with XSM On-board Chandrayaan-2”, Indian Planetary Science Conference, PRL, Ahmedabad, 19-21 Feb., 2020.
26. “Compton Spectro-Polarimetry: Possibilities for Future X-ray Mission”, $4^{th}$ National Conference on Recent Trends in the study of Compact Objects, IUCAA, Pune, 17-20 April, 2019.

**Shashikiran Ganesh**

27. “Observations of cometary dust in the optical spectrum”, International Conference on Infrared Astronomy and Astrophysical Dust (IRAAD-2019), IUCAA, 22-25 October, 2019.
28. “Minor bodies of the Solar System”, Science with Subaru workshop, TIFR, Mumbai, 18-20 Dec, 2019.

**Veeresh Singh**

29. “Search for high-redshift galaxies in deep fields”, Australia-India Research and Development in Radio Astronomy Meeting, Lonavala, Pune, 13-15 Nov, 2019.
30. “Positions of Extragalactic radio sources using VLBI technique”, Very Long Baseline Interferometry (VLBI) technique for geodetic applications in India, IIT Kanpur, 3-4 Mar, 2020..

**Vishal Joshi**

31. “Novae: The major source of $^{13}$C”, 150 years of periodic table, Indian Institute of Astrophysics (IIA), Bangaluru, 16-19 Nov, 2019.
32. “Molecules and Dust in nova ejecta”, International Conference on Infrared Astronomy and Astrophysical Dust (IRAAD), Inter-University Centre For Astronomy and Astrophysics (IUCAA), Pune, 22-25 Oct, 2019.
33. “Novae: The major source of $^{13}$C”, Emerging trends in Science and Technology: Challenges & Opportunities, Tolani college of Arts and Science, Adipur, Gujarat, 4 Feb, 2020.

**Solar Physics**

**Brajesh Kumar**

34. “Solar Structure, Dynamics, and Solar Oscillations”, three lectures during “Short Course on Space Weather” organized by UN-CSSTEAP, PRL, Ahmedabad, 14-27 Nov, 2019.

**Bhuwan Joshi**

35. “The Sun and Space Weather”, Workshop on Fundamentals of Astronomy, B.M. Birla Planetarium, Jaipur, 6-8 Jan, 2020.
36. “Exploring solar eruptions with multi-wavelength observations from ground and space”, Workshop on Fundamentals of Astronomy, B.M. Birla Planetarium, Jaipur, 6-8 Jan, 2020.

**Girjesh R. Gupta**

37. “Observations and modeling of chromospheric evaporation during Solar micro-flares”, IRIS-10 meeting, Christ University, Bangalore, 4-8 Nov, 2019.
38. “Observations and modeling of chromospheric evaporation during Solar micro-flares”, Asia Pacific Solar Physics Meeting (APSPM-2020), IUCAA, Pune, 3-7 Feb, 2020.

**Nandita Srivastava**

39. “Science results using ground-based instruments in solar astronomy”, one-day workshop on “Ground-based instrumentation for solar astronomy”, $38^{th}$ meeting of the Astronomical Society of India, IISER, Tirupati, 13 Feb, 2020.
40. “New challenges in Solar Physics Research”, Young Astronomers’ Meet, Kodaikanal Observatory, IIA, 23-27 Sep, 2019.
41. “Solar Origins of Space Weather & Coronal Mass Ejections”, two lectures during “Short Course on Space Weather” organized by UN-CSSTEAP, PRL, Ahmedabad, 14-27 Nov, 2019.

42. “CME Initiation & CME propagation in 3d space”, two lectures at COSPAR capacity building workshop on Coronal and Interplanetary Shocks, Kodaikanal Observatory, IIA, 6-17 Jan, 2020.

**Ramit Bhattacharyya**

43. “Physics of the solar coronal transients”, Annual Theory Physics Days (ATPD), PRL, Ahmedabad, 22-24 Apr, 2019.

**Rohan E. Louis**

44. “Overview of telescopes and post-focus instruments”, three lectures during “Short Course on Space Weather” organized by UN-CSSTEAP, PRL, Ahmedabad, 14-27 Nov, 2019.
45. “Solar differential rotation & heliographic coordinates of sunspots”, Lab exercises during “Short Course on Space Weather” organized by UN-CSSTEAP, PRL, Ahmedabad, 14-27 Nov, 2019.
46. “The importance of the solar chromosphere Recent insights from high resolution observations”, $38^{th}$ meeting of the Astronomical Society of India, IISER, Tirupati, 13-17 Feb, 2020.
47. “MAST data archive and preliminary science results”, one-day workshop on “Ground-based instrumentation for solar astronomy, $38^{th}$ meeting of the Astronomical Society of India, IISER, Tirupati, 13 Feb, 2020.

**Shibu K. Mathew**

48. “Multi-Application Solar Telescope”, Asia Pacific Solar Physics Meeting (APSPM-2020), IUCAA, Pune, 3-7 Feb, 2020.
49. “Multi-Application Solar Telescope”, one-day workshop on “Ground-based instrumentation for solar astronomy”, $38^{th}$ meeting of the Astronomical Society of India, IISER, Tirupati, 13 Feb, 2020.

**A. Raja Bayanna**

50. “Image restoration techniques: Adaptive Optics”, one-day workshop on “Ground-based instrumentation for solar astronomy”, $38^{th}$ meeting of the Astronomical Society of India, IISER, Tirupati, 13 Feb, 2020.

**Planetary Sciences**

**Anil Bhardwaj**

51. “Video Lecture on ”Module 7-Solar system Astronomy”-Chapter 7.5-”Planetary science””, SWAYAM program of Ministry of Human Resource Development (MHRD), Online, 2019.
52. “Exploring Moon: 50 Years of Apollo Landing”, Popular lecture Organized by Indian Society of Geomatics Ahmedabad Chapter, Indian Society of Remote Sensing Ahmedabad Chapter, IEEE Geoscience and Remote Sensing Society-Gujarat Chapter, M.G. Science Institute, Ahmedabad, 20 July, 2019.
53. “Space Sciences and Planetary Exploration”, National Conference on Polar Sciences, NCAOR, Goa, 21 August, 2019.
54. “Indian Planetary and Space Missions”, Student Conference on Optics and Photonics, PRL, Ahmedabad, September 24, 2019.
55. “Indian Planetary Missions”, Federation of Indian Geosciences Associations, 2nd Triennial Congress, NGRI, Hyderabad, October 14, 2019.
56. “A New Perspective on Moon-Solar Wind Interaction after Chandrayaan-1 Mission”, AOGS $16^{th}$ Annual Meeting, Singapore, July 30, 2019.
57. “Science from the Chandrayaan-2 Mission”, AOGS $16^{th}$ Annual Meeting, Singapore, 28 July-2 August, 2019.
58. “Planetary Exploration”, 50 years of Excellence in Space Science Research, Golden Jubilee Celebrations, Space Physics Laboratory, VSSC, Trivandrum, 8-9 April, 2019.
59. “Indian Planetary and Space Missions and Sciences”, A Joint Conference on ‘Astrophysics and Planetary Sciences’ of Israel Academy of Sciences and Humanities and the Indian National Science Academy, Jerusalem, Israel, Dec. 2-3, 2019.

**Amit Basu Sarbadhikari**

60. “In-situ Planetary Exploration”, Structured Training Program (STP) organized jointly by SAC and PRL, PRL, Ahmedabad, 22-28 January, 2020.
61. “Water in the Interior of the Moon”, Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February, 2020.

**Jayesh P. Pabari**

62. “Interplanetary Dust: Science, Technology, Engineering and Mathematics”, National Conference on Science, Technology, Engineering and Mathematics, GCET, Vallabhvidyanagar, 27 September, 2019.
63. “Interplanetary Dust Science”, Post-TEQIP Sponsored Workshop, GEC, Rajkot, 31 December, 2019.
64. “Interplanetary Dust around Venus”, Indian Planetary Science Conference (IPSC), PRL Ahmedabad, 20 February, 2020.

**Karnnam Durga Prasad**

65. “A Comprehensive 3D Model for Understanding the Thermophysical behaviour of the Moon”, COMSOL International Conference, Bangalore, 27-29 Nov. 2019.
66. “Heat Flow and Geophysical Exploration of the Moon”, Indian Planetary Science Conference (IPSC -2020), PRL, Ahmedabad, 19-21 February, 2020.

**Kuljeet K. Marhas**

67. "$^{7}$Be and Super flare", Annual Theory Day, PRL, Ahmedabad, 24 April,. 2019.
68. "Understanding protoplanetary disk formation via organics from Meteorites", $7^{th}$ Asian Network for natural and unnatural materials, ANUUM VII, AMA, Gujarat, 27-28 September, 2019.
69. "Stellar Nucleosynthesis and evolution of Early Solar System", Award lecture, $32^{nd}$ ISMAS Conference, BARC training School, Mumbai, 27-29 Nov, 2019.
70. "Active Early Sun: Irradiation in the first few million years", Union Award Lecture, Fall meeting AGU, San Franciso, USA, 9-13 Dec, 2019.
71. "DUSTy windows to formation of elements", ASI International meeting on "150 years of periodic table", Indian Institute of Astrophysics, Bangalore, 16-20 Dec., 2019.
72. "Messengers from Space", Indian Planetary Science Conference (IPSC -2020), PRL, Ahmedabad, 19-21 February, 2020.

**Megha Bhatt**

73. "Global mapping of lunar refractory elements", Pressing for Progress, University of Hyderabad, 19-21 September, 2019.
74. "The role of Cross-calibration/validation in the data reduction of NIR measurements", Chandrayaan-2 Data Analysis Workshop, ISSDC, Byalalu, Bengaluru, 6 -7 January, 2020.
75. "Lunar swirls: The enigma", Indian Planetary Science Conference, PRL, Ahmedabad, 19-21 September, 2019.

**M. Shanmugam**

76. "In-situ planetary investigations: Instrument and Science", Structured Training Program on Scientific satellite missions: payload definition, development and data utilization, PRL, Ahmedabad, 27-28 January, 2020.
77. "Exploration of Mars with Mars Robotic Laboratory", Indian Planetary Science Conference, PRL, Ahmedabad, 19-21 February, 2020.

**Neeraj Srivastava**

78. "Polar Science", $2^{nd}$ Lunar Science Meet, ISRO HQ, June 1314, 2019.
79. "Science and Technical aspects of Lunar Sample Return", Indian Planetary Sciences Conference (IPSC), PRL, Ahmedabad, 19-21 February, 2020.

**Varun Sheel**

80. "Martian lower atmosphere: Current views and future directions", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February, 2020.

**S. A. Haider**

81. "Expected science returns from ISROs future planetary missions: Mars and Venus", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February, 2020.

**Shiv K. Goyal**

82. "Test and Simulation of Planetary and Space Mission Payloads using Balloon Platform", Two Days Users Meeting at Balloon Facility, Hyderabad, 20-21 January, 2020.

**Space and Atmospheric Sciences**

**Dibyendu Chakrabarty**

83. "Living in a stellar neighborhood", VIkram Sarabhai Innovation CompetitiON (VISION)-2019, PRL, Ahmedabad., 31 May, 2019.
84. ""Space weather: a broad perspective 3 lectures and "Study of optical signatures of space weather events"- 2 project lectures", "A short course on Space weather", organized by The Center for Space Science and Technology Education in Asia and Pacific (CSSTEAP, affiliated to the United Nations), PRL, Ahmedabad, November 18-27, 2019.
85. "Six invited lectures on various aspects of Space weather", in the Third PG Course of CSSTEAP in "Global Navigation Satellite Systems" (GNSS-3), Space Applications Center, ISRO, Ahmedabad, January, 2020.

**Duggirala Pallamraju**

86. "Road ahead for Space Sciences in India", Golden Jubilee Celebrations of Space Physics Laboratory, SPL, Trivandrum, April 8-9, 2019.
87. "New results on large scale upper atmospheric variability" (Keynote lecture) in", National Conference on Space and Atmospheric Sciences, Sanjay Ghodawat University, Kolhapur, May 10-11, 2019.
88. "Space Weather: Science and Applications", Inaugural lecture in Short Course on Space Weather organized by UN-CSSTEAP, Physical Research Laboratory, Ahmedabad, November 14-27, 2019.
89. "Overview of Space Physics", talk delivered to the participants of the ISRO Induction Training Program, PRL, Ahmedabad, 22 November 2019.
90. "New directions in upper atmospheric research", talk delivered in the PRL Alumni Association: Scientific Workshop on "Research at PRL: Synoptic Perspective", PRL, Ahmedabad, December 24, 2019.
91. "Aeronomy Missions", in ISROs Structured Training Program (STP) held at, PRL-SAC, Ahmedabad, January 24-28, 2020.

**Lokesh Kumar Sahu**

92. "Remote sensing of trace gases in the atmosphere over South Asia: Challenges and opportunities", URSI Regional Conference on Radio Science (RCRS) 2020, IIT (BHU) Varanasi, India, February 12-14, 2020.
93. "Volatile organic compounds and ozone: Implication to atmospheric chemistry", Institute of Environment and Sustainable Development, BHU, Varanasi, 15 February 2020.

**Narendra Ojha**

94. "Modelling the atmospheric chemistry and dynamics over India", National conference on Recent Trends in Environmental Pollution and Disaster Risk Reduction (RTEPDRR-2020), FICCI, New Delhi, February 6-7, 2020.

**Ravindra Pratap Singh**

95. "Recent results on the MLT dynamics using spectrographic measurement of OH(6-2) and O2(0-1) band nightglow emissions and corresponding temperatures", $1^{st}$ National Conference on Space and Atmospheric Science (NCSAS-2019), Sanjay Ghodawat University, Kolhapur, May 10-11, 2019.

**S. Ramachandran**

96. "Aerosol Characteristics and Radiative Forcing", Institute for Advanced Sustainability Studies, Potsdam, Germany, 16 April 2019.
97. "Atmospheric Aerosols: Observations and Simulations", Guest Colloquium, The Freie Universitt Berlin, Germany, 8 July 2019.
98. "Atmospheric Aerosols: Observations and Simulations", Open Seminar Series Geoscience and Remote Sensing, Technical University, Delft, Netherlands, 26 November 2019.
99. "Atmospheric Aerosols: Observations and Simulations", Distinguished Lecture Series, Institute for Environmental Sciences and Geography, University of Potsdam, Potsdam, Germany, 9 December 2019.
100. "Aerosols: Observations and Simulations", Institute Seminar, Max Planck Institute for Chemistry, Mainz, Germany, 11 December 2019.

**Shyam Lal**

101. "Air pollution in India", the Asian Air Pollution Workshop (AAPW-5), Banaras Hindu University, Varanasi, Nov 5-6, 2019.

**Som Kumar Sharma**

102. "Investigations of Earth Atmospheric Processes: A Key of Disaster Monitoring", Recent Advances in Anthropogenic Disaster Monitoring (RAADM-2019), Chennai, 23 Oct 2019.
103. "Solar influence on middle atmospheric processes", Short Course on Space Weather, organised by CSSTEAP (Affiliated to the United Nations), PRL, Ahmedabad, 25 November 2019.
104. "Earth's Atmosphere and its Exploration", LIDAR Science and Technology under Space Education and Research Foundation (SERF) through webinar, ., 9 Sept 2019.
105. "World of Atmospheric LIDAR-Part I", LIDAR Science and Technology under Space Education and Research Foundation (SERF) through webinar, ., 10 Sept 2019.
106. "World of Atmospheric LIDAR-Part II", LIDAR Science and Technology under Space Education and Research Foundation (SERF) through webinar, ., 11 Sept 2019.
107. "Exploration of the Atmosphere using LIDAR", LIDAR Science and Technology under Space Education and Research Foundation (SERF) through webinar, ., 12 Sept 2019.

**Geosciences**

**Arvind Singh**

108. "Role of oceans in climate change", International conference on Asian Network for Natural & Unnatural Material, Gujarat University, Ahmedabad, 28 September, 2019.
109. "IIOE-2 (ECSN) research activities by Indian group", JCOMM Observations Coordination Group OCG (OCG-10) Regional Workshop, Jakarta, Indonesia, 8 April, 2019.
110. "Biogeochemistry of the northern Indian Ocean", JCOMM Observations Coordination Group OCG (OCG-10) Regional Workshop, Jakarta, Indonesia, 8 April, 2019.
111. "Increase in summer monsoon rains in northeast India during ENSO periods", Indo-US Bilateral Symposium on climate risk and reconstruction, IISER Mohali, Mohali, 2 January, 2020.
112. "Air-sea Chemical FluxesImpacts on Biogeochemistry and Climate", EGU General Assembly-2019 session, Vienna, Austria, 2019.

**Neeraj Rastogi**

113. "Chemistry of atmospheric aerosol", International Conference "Asian Network for Natural /& Unnatural Materials (ANNUM VII), Department of Chemistry, Gujarat University, Ahmedabad, 27-29 September, 2019.
114. "Sources and Characteristics of Organic Aerosols over Indian Monsoon Region", International Conference "Asian Summer Monsoon Anticyclone: Gateway of Surface Pollutants to the stratosphere", SRM Institute of Science and Technology, Chennai., 10-11 February, 2020.

**Rajendra D. Deshpande**

115. "Isotope Applications in Groundwater Hydrology", $3^{rd}$ Indian National Groundwater Conference (INGWC-2020), Groundwater Resources Management for Sustainable Development: Special Emphasis on Coastal and Urban Environment, Centre for Water Resources Development and Management (CWRDM), Kozhikode, 19 February, 2020.
116. "Problem Solving Techniques in Isotope Applications for Hydrological Research", National Workshop on Problem Solving Techniques in Sciences, M.S. University of Baroda, Vadodara, 30 November, 2019.

**Theoretical Physics**

**Hiranmaya Mishra**

117. “Color superconductivity in magnetized quark matter”, Institute of Physics, Bhubaneswar, Institute of Physics, Bhubaneswar, 27 Dec 2019.

118. “Estimating of transport coefficients in effective models of QCD”, International workshop on ”Myriad colorful ways of understanding QCD matter”, ICTS, Bengaluru, 4 April 2019.

**Partha Konar**

119. “Boosted Fat jet & Jet substructure”, ANOMALIES 2019, IIT Hyderabad, 18-24 July, 2019.

120. “AI initiation presentation”, at the Workshop in High Energy Physics

**Satyajit Seth**

121. “Analytic Structure of Higgs+$n$-gluon One Loop Amplitude”, International workshop on Precision QCD @ LHC, IIT Hyderabad, 28-31 Jan 2020. Phenomenology (WHEPP), IIT Guahati, December 2019

**Srubabati Goswami**

122. “Phenomenological and Theoretical perspectives in Neutrino Physics”, TeVPA 2019, Sydney, Australia, 4-8 December, 2019.

123. “Implication of dark-LMA solution for neutrino-less double beta Decay”, PASCOS 2019, University of Manchester, 1-5 July, 2019.

**V. K. B. Kota**

124. “Shell model analysis of multiple SU(3) algebras in nuclei”, International Workshop on Shapes and Dynamics of Atomic Nuclei: Contemporary Aspects (SDANCA-19), Bulgarian Academy of Sciences Hotel, Sofia (Bulgaria), 3-5 October, 2019.

125. “Lie algebras and group-subgroup chains in nuclei”, SERB school on “Role of Symmetries in Nuclear Physics”, Amity University, Noida, 10-23 October, 2019.

**Atomic, Molecular and Optical Physics**

**Ashok K. Singhvi**

126. “Luminescence Dating: Meteorites, Archeology and Complex Environments”, National Workshop on Luminescence Dating, National Geophysical Research Laboratory, Hyderabad, 711 December 2019.

127. “Luminescence Dating, Principles, Applications and Implications (6 lectures)”, Oil India-INSA Workshop on Quantitative Geomorphology, IIT Gandhinagar, 721 February 2020.

128. “Societal Societal Relevance of- and Scientific Challenges for- Geosciences as Services”, Inaugural Lecture at the Oil India INSA workshop on Quantitative Geomorphology, IIT Gandhinagar, 721 February 2019.

**Bhalamurgan Sivaraman**

129. “Biography of molecules beyond Earth”, Asian Network for Natural & Unnatural Materials, Gujarat University, Ahmedabad, 2729 September 2019.

130. “Laboratory astrochemistry and lunar exosphere”, Chandrayan 2 Data Workshop, ISSDC, ISRO, Bangalore, 67 January 2020.

131. “Complex molecules in impact induced shock conditions”, 6th National Symposium on Shock Waves-2020, Department of Aerospace Engineering, IIT-Madras, Chennai, 2628 February 2020.

132. “Complex molecules in astrochemical impact conditions”, IAU S350: Laboratory Astrophysics: from Observations to Interpretation, Jesus College, University of Cambridge, UK., 1419 April 2019.

**Bijaya K. Sahoo**

133. “Recent Progresses and Challenges in Atomic Coupled cluster Theory”, Laser Spectroscopy as a tool for Nuclear Physics Workshop, Espace de Structure Nucleaire Theorique (ESNT) of the Commissariat a lEnergie Atomique et aux Energies Alternatives (CEA), Saclay-Paris, France., 711 October 2019.

134. “Analytical Response Relativistic Atomic Many body Method”, 8th Topical conference on Atomic and Molecular Collisions for Plasma Applications, Indian Institute of Technology, Roorkee, 35 March 2020.

**Goutam K.Samanta**

135. “Contemporary Optics at Physical Research Laboratory: Structured optical beams”, Symposium on Intense Laser Application and Innovation ., TIFR Hyderabad, 2729 January 2020.

136. “Classical and quantum implementation of structured optical beams”, 107th Indian Science Congress, University of Agriculture and Science, Bangalore, 37 January 2020.

137. “High brightness entangled photon source for quantum communication”, International Symposium on Quantum Information Technology, ISQIT 2019, Pune, 25 December 2019.

138. “Structured optical beams”, Contemporary Trends in Optics 2019, IISER Kolkata, 2023 May 2019.

**Monika Devi**

139. “Multispectral luminescence studies in feldspar”, Invited talk in Christ College, Kerala, January 29, 2020

**Naveen Chauhan**

140. “Radioactivity Measurements for Luminescence Dosimetry”, National Workshop on Luminescence Dating, National Geophysical Research Laboratory, Hyderabad, 7-11 December 2019.

141. “Luminescence Dose Distribution and Analysis”, National Workshop on Luminescence Dating, National Geophysical Research Laboratory, Hyderabad, 711 December 2019.

142. “Unconventional luminescence dating techniques”, National Workshop on Luminescence Dating, National Geophysical Research Laboratory, Hyderabad, 711 December 2019.

**Rajesh K. Kushawaha**

143. “Photoionization of Polyatomic Molecules: Molecular Structure, Ultrafast Dynamics and Molecular Movie”, Ultrafast Sciences (UFS 2019), IIT Mumbai, 79 November 2019.

**Ravindra Pratap Singh**

144. “Indigenous Satellite Based Quantum Communication”, DTDI Workshop, ISRO HQ Bangalore, 1415 November 2019.

145. “Single photon and entangled photon sources: Generation and characterization”, International Symposium on Quantum Information Technology (ISQIT 2019), DIAT Pune, 25 December 2019.

146. “Satellite based quantum communication: International and national status, National Mission on Quantum Technologies”, Consultative Meeting, IISER Mohali, 2223 November 2019.

147. “Orbital angular momentum entanglement of down converted photons and the pump modes”, International Conference on Optics and Electro-optics (ICOL 2019), IRDE Dehradun, 1822 October 2019.

148. “Non-separable States of Polarization and Orbital Angular Momentum of Light: From Classical to Quantum”, International Symposium on Photonics and Plasmonics (ISPP-2019), Central University of Rajasthan, Ajmer, 2324 September 2019.

149. “Duality in entanglement: Polarization and orbital angular momentum of photons”, Quantum Frontiers and Fundamentals (QFF-2020), RRI Bangalore, 1318 January 2020.

150. “Quantum Aspects of Orbital Angular Momentum of Light”, The Summer School on Quantum Information and Quantum Technology (QIQT-2019), IISER Kolkata, 1323 July 2019.

151. “Quantum Information Processing with Structured Light”, The Summer School on Quantum Information and Quantum Technology (QIQT-2019), IISER Kolkata, 1323 July 2019.

# Lectures at Universities / Institutions

**Astronomy and Astrophysics**

**Aveek Sarkar**

1. "Understanding the atmosphere of our nearest star using numerical simulation", Indian Institute of Science Education and Research (IISER), Tirupati, December 2, 2019

**Mudit K. Srivastava**

2. "Telescopes and Instrumentation in Astronomy", National Institute of Technology, Tiruchirappalli, 29 November, 2019

**Vishal Joshi**

3. "Nova: an important object in the sky", Christ College, Rajkot, January 31, 2020

**Lokesh K. Dewangan**

4. "Probing the birth of most massive stars", Raman Research Institute (RRI), Banglore, January 10, 2020

**Solar Physics**

**Ashok Ambastha**

5. "Recent advances in observing the Sun from ground and space", DST-Inspire camp at Sir Padampat Singhania University, Bhatewar, Udaipur, November 27, 2019

**Bhuwan Joshi**

6. "Propagation of coronal mass ejections from near-Sun to near-Earth environment", School of Space Research, Kyung Hee University, Suwon, South Korea, September 3, 2019
7. "Eruptions of magnetic flux ropes from the Sun and their interplanetary consequences", Korea Astronomy and Space Science Institute, Daejeon, South Korea, September 10, 2019
8. "Solar structure and processes", Course lectures (12 lectures), Aryabhatta Research Institute of Observational Science (ARIES), Nainital, Uttarakhand, February 19-24, 2020

**Sushree Sangeeta Nayak**

9. "Origin and evolution of the three-dimensional magnetic null points in the solar atmosphere", Institute of Astrophysics of the Canary Islands, Spain, November 29, 2019

**Planetary Sciences**

**Anil Bhardwaj**

10. "Indian Planetary Missions", Guest of Honour Lecture, Indian Institute of Tropical Meteorology, Pune, November 17, 2019

**Jayesh P. Pabari**

11. "Past, Present and Future in Electronics", Invited Talk at VGEC, Chandkheda, Ahmedabad, 6 August, 2019

**Megha Bhatt**

12. "Problem Solving Methods: Lunar Elemental abundances mapping", Workshop on problem solving skills, Physics Department, Faculty of Science, Maharaja Sayajirao University of Baroda, Vadodara, 25-30 November, 2019

**Vijayan S.**

13. "Planetary remote sensing of Moon and Mars", INSA Lecture by Young Scientist at Bharathidasan University, Trichy, Tamilnadu, September 3, 2019

**Space and Atmospheric Sciences**

**Dibyendu Chakrabarty**

14. "Space weather", at the School of Physics and Material Science at the Thapar Institute of Engineering and Technology (TIET), Patiala, as part of the VISION-2019 shortlisted project inspection visit, December 18, 2019

**Harish Gadhavi**

15. "Atmospheric Radiative Transfer", Lecture series of 12 lectures, at St. Xaviers College, Ahmedabad, .

**Narendra Ojha**

16. “Atmospheric chemistry and dynamics: modelling perspectives”, Department of Geophysics, Banaras Hindu University (BHU), Varanasi, 15 February 2020

**Shyam Lal**

17. “20 lectures on “Importance of atmospheric trace species and their measurement techniques””, Centre for Oceans, Rivers, Atmosphere and Land Science (CORAL), IIT, Kharagpur, Oct 14-25, 2019

**Geosciences**

**Rajendra D. Deshpande**

18. “Frontiers of Hydrology Research-Role of Isotope Tracer Applications”, Interdisciplinary Centre for Water Research (ICWaR) Seminar Series, IISc, Bangaluru, 16 July, 2019
19. “Water Resources of IndiaChallenges and Solutions”, PRL IAPT Dr. Vikram Sarabhai Lecture, at PRL, Ahmedabad, 27 January, 2020

**Arvind Singh**

20. “Climate Modelling”, lectures delivered to II Semester M.Sc. students at Gujarat University, Ahmedabad, January-April, 2019. (8 lectures)
21. “‘Sustainable forest management’ and ‘Coastal zone management’ ”, lectures delivered to III semester M.Sc. students at Gujarat University, June-August, 2019.(8 lectures)
22. “‘Isotope Geochemistry’”, lectures delivered to I semester M.Sc. students at Gujarat University, Ahmedabad, July-October, 2019. (4 lectures)
23. “‘Introduction to Paleoclimatology’ ”, lectures delivered to I semester M.Sc. students at Gujarat University, Ahmedabad, August-October, 2019. (6 lectures)
24. “Hydrosphere”, lectures delivered to the International Earth Science Olympiad (International Earth Science Olympiad) 2019 students at Anna University (all the four Indian students secured 3 gold, 4 silver and 3 bronze medals in total for India during 26 Aug-3 Sep 2019 in IESO held in South Korea)., May 20-22, 2019 & August 22-23, 2019. (12 lectures)

**Theoretical Physics**

**Partha Konar**

25. “Status on Solar flair prediction using Machine learning”, during DTDI AI/ML training-II, February 2020
26. “Presentation and tutorials AI and Machine learning lecture and hands on tutorial sessions”, during ANOMALIES 2019 held at IIT Hyderabad, July 2019
27. “Machine learning in HEP”, during Annual Theory Discussion Days (ATDD’19), April 2019

**Srubabati Goswami**

28. “Synergy between Long baseline and Atmospheric Neutrino Experiments”, LeverHulme Seminar, Imperial College, London, July 2019
29. “New Physics @nuSTORM”, Invited seminar at The University of Oxford, July 2019

**Ketan M. Patel**

30. “An introduction to Quantum Mechanics”, series of 11 lectures given at the Advanced BSc (Physics) Programme 2019 held at St. Xaviers College, Ahmedabad, May-June, 2019

**Navinder Singh**

31. “A road map pf Nickelate superconductivity”, Central University of Punjab, Bathinda, November 5, 2019
32. “Set of three lectures on solid state theory”, MS university, Vododara, November 30, 2019

**Atomic, Molecular and Optical Physics**

**Ravindra Pratap Singh**

33. “Quantum Technology: Present and Future”, Talk delivered at SAC Ahmedabad, August 16, 2019
34. “Optical Vortices and Entanglement Duality”, Colloquium at IISER Pune, February 3, 2020
35. “Optical Vortices and their Applications”, International Day of Light Seminar, IIT Guwahati., May 16, 2019

**Ashok K. Singhvi**

36. “Luminescence Dating, Principles, Applications and Implications.”, Institute Colloquium, National Geophysical Research Laboratory, Hyderabad, December 8, 2019
37. “Science and Technology of the future and the Challenges for Academies and Academicians”, Talk delivered at Humboldt Kolleg at Raichak West Bengal, University of Jadavpur, December 21, 2019
38. “Some reflections on our role in Nation Building”, Delivered at Central Salt and Marine Chemicals Research Institute, Bhavnagar, December 30, 2019
39. “Science and Technology of the future and the Role of Academia”, Lecture at IIT Roorkee, February 22, 2020
40. “Science and Technology of the future and the Role of Academia”, Delivered at National Institute for Advanced Studies, Bangaluru, March 5, 2020

**Bijaya K. Sahoo**

41. “Revisiting Atomic Parity Nonconservation Studies and Recent Developments”, Seminar at Institute de Physique de Nice, Universite Cote dAzur, CNRS, France, October 4, 2019

# Science Outreach Talks by PRL Scientists

**Astronomy and Astrophysics**

**Santosh Vadawale**

1. “New Avenues of Indian Hard X-ray Astronomy”, Science Day workshop at IIT Kanpur, Kanpur, on 28-02-2020

**Vishal Joshi**

2. “A journey through the solar system”, Delivered at M N J Patel Secondary School, Surat, on 05-02-2020
3. “wonderful universe”, Outreach talk delivered in rural areas at Anapurgadh Village, DhaneraTaluka, Banaskantha, on 26-02-2020
4. “Fascinating world of exoplanets”, Outreach talk delivered at V S Patel collage of Arts and Science, Bilimora, Gujarat, on 22-02-2020

**Solar Physics**

**Bireddy Ramya**

5. “Engineering in Science”, a one-day science outreach activity of USO/PRL at Jawahar Navodaya Vidyalaya, Mavli, Udaipur to commemorate National Science Day with the theme “Women in Science”, on 03-03-2020

**Bhuwan Joshi**

6. “Sun and Space Weather”, workshop on “Model Rocketry” conducted by Vikram A. Sarabhai Community centre and Atal Tinkering Lab (a NITI Aayog Program) at Abhinav School, Udaipur, on 17-07-2019
7. “Solar system and space exploration”, Maharana Mewar Vidya Mandir, Udaipur, on 25-01-2020

**Brajesh Kumar**

8. “Career Prospects in Science”, a one-day science outreach activity of USO/PRL at Jawahar Navodaya Vidyalaya, Mavli, Udaipur to commemorate National Science Day with the theme “Women in Science”, on 03-03-2020

**Girjesh R. Gupta**

9. “Dynamic Sun”, a one-day science outreach activity of USO/PRL at Jawahar Navodaya Vidyalaya, Mavli, Udaipur to commemorate National Science Day with the theme “Women in Science”, on 03-03-2020
10. “Sun and solar activity”, to school students on World Space Week celebration at Udaipur Solar Observatory, Udaipur, on 10-10-2019

**Rohan E. Louis**

11. “Introduction to Solar Physics at USO”, Kendriya Vidyalaya Eklinggarh, Udaipur during Telescope Making Workshop organized by Vigyan Prasar, Delhi, on 09-04-2019
12. “Introduction to our Sun”, Jawahar Navodaya Vidyalaya, Mavli, Udaipur during Telescope Making Workshop organized by Vigyan Prasar, Delhi, on 10-06-2019
13. “World Space Week and Space Exploration Events”, to school students on World Space Week celebration at Udaipur Solar Observatory, Udaipur, on 10-10-2019
14. “Our daystar The Sun & Research at USO”, a one-day science outreach activity of USO/PRL at Jawahar Navodaya Vidyalaya, Mavli, Udaipur to commemorate National Science Day with the theme “Women in Science”, on 03-03-2020

**Sushree Sangeeta Nayak**

15. “National science Day@2020; Women in Science”, a one-day science outreach activity of USO/PRL at Jawahar Navodaya Vidyalaya, Mavli, Udaipur to commemorate National Science Day with the theme “Women in Science”, on 03-03-2020

**Planetary Sciences**

**Anil Bhardwaj**

16. “Science and Challenges of Indian Planetary Mission”, DST INSPIRE Science Camp at Indrashil University, Kadi, Mehsana, Gujarat, on 06-01-2020

**Megha Bhatt**

17. “The Moon: Gateway to the Stars”, World Space Week Celebration, Udaipur Solar Observatory, PRL, Udaipur, on 10-10-2019

**Geosciences**

**Rajendra D. Deshpande**

18. “Societal Problems of Water Resources”, outreach talk delivered in rural areas at Anapurgadh Village, Dhanera Taluka, Banaskantha, on 26-02-2020

**Theoretical Physics**

**Srubabati Goswami**

19. “Neutrinos: The invisible messenger”, Invited talk, DST-INSPIRE camp, Indrashil University, Gujarat, 03-01-2020
20. “The story of the Neutrino”, Leverhulme Trust lecture delivered to high-school students, Imperial College London, 19-07-2019
21. “Women in Science: Challenges and Way Forward”, Talk delivered on the occasion of National Science Day, PRL, 29-02-2020

**Atomic, Molecular and Optical Physics**

**Ashok K. Singhvi**

22. “Ethics in Science Education, Research and Governance”, Popular talk, Central University Punjab, Bathinda, 21-05-2019
23. “Writing a scientific paper? It is Easier than most think”, Popular Talk Delivered at Central University Punjab, Bathinda, on 22-05-2019
24. “My thoughts on our role as teacher and Why Earth Sciences are becoming ever so important?”, Popular talk delivered at Central University Punjab, Bathinda, on 23-05-2019
25. “Initiating a career in Science”, Inaugural lecture for the initiation of Graduate students. Ganpat University, Mehsana, on 25-06-2019
26. “Ethics in Science Education, Research and Governance”, Delivered at Indian Institute of Chemical Technology, Hyderabad, on 18-08-2019
27. “Ethics in Science Education Research and Governance”, Talk Delivered at National Geophysical Research Laboratory, Hyderabad, on 08-11-2019

# Area Seminar by visitors

**Dr. Prithish Halder**

1. “A comprehensive study of comet dust at different heliocentric distances for varying radiation pressure”, Assam University, Silchar, on 18-04-2019

**Dr. Siddharth Dwivedi**

2. “Reconstructing heavy Higgs boson masses in Leptophilic 2HDM”, Indian Association for Cultivation of Science (IACS) Kolkata, on 02-05-2019

**Mr. Supriyo Ghosh**

3. “Spectroscopic and photometric study of cool and evolved stars”, Satyendra Nath Bose National Centre for Basic Sciences, Kolkata, on 09-05-2019

**Mr. Suvadip Sinha**

4. “Tracking of solar eruptive filaments and finding the temporal connection with associated flare-CME events”, CESSI, Indian Institute of Science Education and Research, Kolkata, on 03-06-2019

**Prof. Ji-Hyung Park**

5. “Anthropogenic perturbations to greenhouse gas emissions from Asian river systems”, Ewha Womans University, Seoul Republic of Korea, on 07-06-2019

**Mr. Ramkumar P. R.**

6. “Application of Gold encapsulated Carbon Nano-Spheres (Au@CNS) as Gamma Ray Detectors and energy source in space satellites”, Dept. of Physics, Anna University, Chennai, on 21-06-2019

**Dr. B. Prasanna Venkatesh**

7. “Cooperative Effects in Closely Packed Quantum Emitters with Collective Dephasing”, IIT Gandhinagar, on 20-07-2019

**Dr. Kinjalk Lochan**

8. “Quantum Fields in Cosmology : The omnipresent de Sitter and theinvariantvacuumnoise”, IISER Mohali, on 25-07-2019

**Dr Tanmoy Mondal**

9. “Probing non-thermal dark matter models at LHC”, Korea Institute for Advanced Study (KIAS), on 02-08-2019

**Prof. Mahan Mj.**

10. “Percolation in hyperbolic groups”, TIFR Mumbai, on 22-08-2019

**Atanu Guha**

11. “Model-independent Astrophysical Constraints onLeptophilic Dark Matter in the Framework of Tsallis Statistics”, BITS Pilani, Goa Campus, on 23-08-2019

**Akariti Sharma**

12. “Static and dynamic property of highly correlated quasi-one-dimensional electron systems at finite temperature”, Punjabi University, Patiala, on 05-09-2019

**Dr Umesh Kadhane**

13. “Colloquium title: Understanding radiation tolerance of PAHs in space and role of collective excitation”, Indian Institute of Space Science and Technology (IIST), Trivandrum, on 18-09-2019

**Dr. Wahab Uddin**

14. “Solar Physics at ARIES Nainital”, Aryabhatta Research Institute of Observational Science (ARIES), Nainital, Uttarakhand, on 19-09-2019

**Ms. Lakhima Chutia**

15. “Atmospheric composition over south Asia: model simulation versus observations”, Centre for Atmospheric Studies, Dibrugarh University, Assam, on 23-09-2019

**Prof. Ady Arie**

16. "Public Lecture : Mixing and Shaping of light beams", Tel Aviv University, Israel, on 25-09-2019

**Dr. Newton Nath**

17. "Recent Developments in $\mu$ - $\tau$ Symmetry", Post-Doctoral Fellow, IHEP, Beijing, on 14-10-2019

**Mr. Arghajit Jana**

18. "Accretion-Ejection Coupling in Black Holes", Indian Centre for Space Physics, Kolkata, on 21-10-2019

**Dr. Kuldeep Suthar**

19. "Many body localization of disordered fermions in optical lattices", Marian Smoluchowski Institute of Physics,Jagellonian University, Krakow, Poland, on 24-10-2019

**Dr. Diganta Das**

20. "Improving the Standard Model prediction of the muon anomalous magnetic moment through high precision determination of the pion electromagnetic form factor and pion charge radius", Dept. Physics & Astrophysics,Univ. Delhi, on 14-11-2019

**Dr. Paramita Dutta**

21. "Physics at Weyl/Superconductor interfaces", Department of Physics and Astronomy, Materials Theory,Uppsala University, Sweden, on 21-11-2019

**Dr. Sunil Chandra**

22. "Challenges in the calibration of astronomical X-ray instruments", Centre for Space Research, North-West University, South Africa, on 22-11-2019

**Dr. Rejish Nath**

23. "Self-bound Doubly-Dipolar Bose-Einstein condensates", IISER Pune, on 10-12-2019

**Dr. Kishalay Choudhury**

24. "X-ray relativistic reflection and testing strong gravity", Inter-University Centre for Astronomy and Astrophysics, Pune, on 12-12-2019

**Dr. Anil Kumar**

25. "Machine-learning and its application in remote sensing data classification", Indian Institute of Remote Sensing, Dehradun, on 12-12-2019

**Dr. Anushree Ghosh**

26. "Reconstruction @MINERvA: From traditional to machine learning techniques", Univ. Padova, Italy, on 13-01-2020

**Dr. Hridesh Kedia**

27. "Drive-specific adaptation in disordered mechanical networks of biostable springs", MIT, USA, on 16-12-2019

**Dr. Samyaday Choudhury**

28. "Sparse star clusters and photometric metallicity maps of the Magellanic Clouds", Macquarie University Sydney Australia, on 24-12-2019

**Dr. Avdhesh Kumar**

29. "Hydrodynamics of Spin Polarized Fluids and Spin Polarization of Particles", Institute of Nuclear Physics PAN, Krakow Poland, on 03-01-2020

**Dr. Tabish Umar Ansari**

30. "Aerosol formation in urban environment: Lessons learnt from modelling winter haze in Beijing", School of Physics, National University of Ireland-Galway, Ireland, on 09-01-2020

**Ms. Komal Kumari**

31. "QBO, ENSO and Solar Cycle Effects in Short-term Non-migrating Tidal Variability on Planetary Wave Timescales from SABER - An Information-Theoretic Approach", Department of Physics and Astronomy, Clemson University, Clemson, on 13-01-2020

**Dr. Giulio Del Zanna**

32. "Understanding the origin of the solar wind with Solar Orbiter, DKIST and Aditya-L1", University of Cambridge, UK, on 30-01-2020

**Prof. S.K. Bhattacharya**

33. "Effect of Monsoon Intra-seasonal Oscillation on the rain isotope variability in northern Bay of Bengal", IIT- Kharagpur, Kharagpur, on 28-01-2020

**Prof. Sanatan Digal**

34. "$Z_N$ Symmetry and confinement-deconfinemt transition in SU(N) + Higgs Theories at finite T", Institute of Mathematical Sciences, Chennai, on 30-01-2020

**Ms. Pooja Setia**

35. "Development of a confined circular-cum-parallel ribbon flare and associated pre-flare activity", Kumaun University, Nainital, on 31-01-2020

**Dr. Tanmoy Modak**

36. "Signatures of extra Yukawa couplings at the LHC and beyond", National Taiwan University, Taipei, on 06-02-2020

**Dr. P. S. Athiray**

37. "Investigating high-energy Solar corona with sounding rockets", Universities Space Research Association, NASA Marshall Space Flight Center, Huntsville, AL, USA, on 12-02-2020

**Dr. Varun**

38. "High Energy Emission from Pulsars with AstroSat-LAXPC", Raman Research Institute, Bangalore, on 13-02-2020

**Dr. Sharad Master**

39. "First evidence for an impact origin of the $>$45 km diameter Simlipal ring structure, Singhbhum Craton, Odisha, India", School of Geosciences, University of the Witwatersrand, Johannesburg, South Africa, on 18-02-2020

**Prof. Subroto Mukerjee**

40. "Bilayer graphene and twisted bilayer graphene: Specular Andreev reflection and thermoelectricity", Dept. of Physics, IISc, on 26-02-2020

**Dr. Bharat Kumar**

41. "Constraints on the moment of inertia of neutron-star/pulsars from GW170817", Center for Computational Sciences, University of Tsukuba Japan, on 27-02-2020

**Dr. Pankaj Bhalla**

42. "Resonant photovoltaic effect in doped magnetic semiconductors.", University of New South Wales, Sydney, Australia, on 28-02-2020

**Dr. Manish N. Sanghani**

43. "Multi-isotopic and (S)TEM Investigations of Presolar Silicates", University of Copenhagen, Denmark, on 06-03-2020

# Technical/Scientific talk given in Hindi

**पोस्टर प्रस्तुति सत्र : 12**

1. “सूर्य अनुरूप सितारे एपिक 211945201 के आसपास एक बाह्य ग्रह (लघु शनि) की खोज”, ऋषिकेश शर्मा, हिंदी तकनीकी सेमिनार, पीआरएल, प्रकार: पोस्टर प्रस्तुति, 2019-04-05
2. “पी. आर. एल. में अनुकूली प्रकाशिकी (एडाप्टिव ऑप्टिक्स) टेस्ट-बेंच प्रयोग”, वैभव दीक्षित, हिंदी तकनीकी सेमिनार, पीआरएल, प्रकार: पोस्टर प्रस्तुति, 2019-04-05
3. “दक्षिण पूर्वी अरेबिआ टेरा में एक फर्श-खंडित क्रेटर का भूवैज्ञानिक अध्ययन: मंगल पर प्रारंभिक आग्नेय प्रक्रियाओं के संभावित प्रमाण”, अल्का रानी, हिंदी तकनीकी सेमिनार, पीआरएल, प्रकार: पोस्टर प्रस्तुति, 2019-04-05
4. “मुकुंदपुरा (सीएम 2) उल्कापिंड में फोरस्टेरिटिक ओलिविन का रंग कैथोडोल्यूमिनेन्स अध्ययन”, शिवानी बालियान, हिंदी तकनीकी सेमिनार, पीआरएल, प्रकार: पोस्टर प्रस्तुति, 2019-04-05
5. “मंगल ग्रह पर रेडियो ग्रहण प्रयोग”, सोनम जीतरवाल, हिंदी तकनीकी सेमिनार, पीआरएल, प्रकार: पोस्टर प्रस्तुति, 2019-04-05
6. “चंद्रमा पर ग्रिमाल्डी बेसिन में हाल ही में हुई ज्वालामुखी और विवर्तनिकी घटनायें”, तनु सिंह, हिंदी तकनीकी सेमिनार, पीआरएल, प्रकार: पोस्टर प्रस्तुति, 2019-04-05
7. “मंगल ग्रह के उल्कापिंड टीसिंट में ट्रेस तत्वों का विश्लेषण तथा कम आकार के स्पॉट के लिए लेजर मापदंडों का अनुकूलन”, गरिमा अरोड़ा, हिंदी तकनीकी सेमिनार, पीआरएल, प्रकार: पोस्टर प्रस्तुति, 2019-04-05
8. “वायुमंडलीय अनुसंधान में सक्रिय सुदूर संवेदन तकनीक”, मलैदेवन, हिंदी तकनीकी सेमिनार, पीआरएल, प्रकार: पोस्टर प्रस्तुति, 2019-04-05
9. “मल्टीचैनल रमन लिडार के उपयोग से अहमदाबाद के बादलों का अध्ययन”, सौरिता साहा, हिंदी तकनीकी सेमिनार, पीआरएल, प्रकार: पोस्टर प्रस्तुति, 2019-04-05
10. “सल्फर समस्थानिक और पृथ्वी विज्ञान में इसके अनुप्रयोग”, संगीता वर्मा, हिंदी तकनीकी सेमिनार, पीआरएल, प्रकार: पोस्टर प्रस्तुति, 2019-04-05
11. “पीआरएल वेबसाइट की सामग्री और सुरक्षा”, गिरीश पड़िया, हिंदी तकनीकी सेमिनार, पीआरएल, प्रकार: पोस्टर प्रस्तुति, 2019-04-05
12. “प्रवृत्ति विश्लेषण - पीआरएल वेबसाइट लॉग”, प्रशांत जांगिड़, हिंदी तकनीकी सेमिनार, पीआरएल, प्रकार: मौखिक प्रस्तुति, 2019-04-05

**मौखिक प्रस्तुति सत्र : 42**

13. “विज्ञान में महिलाओं का योगदान” : सुश्री संगीता नायक, उदयपुर सौर वेधशाला राष्ट्रीय विज्ञान दिवस कार्यक्रम, के दौरान नवोदय विद्यालय (शिक्षा विभाग, भारत सरकार के अधीन एक स्वायत्त संस्था), मावली, उदयपुर, राजस्थान में एक दिवसीय विज्ञान आउटरीच कार्यक्रम, प्रकार: मौखिक प्रस्तुति, 2020-04-03
14. “सूर्य एवम उदयपुर सौर वेधशाला में सौर अध्ययन”: डॉ. रोहन लुइस, उदयपुर सौर वेधशाला राष्ट्रीय विज्ञान दिवस कार्यक्रम, के दौरान नवोदय विद्यालय (शिक्षा विभाग, भारत सरकार के अधीन एक स्वायत्त संस्था), मावली, उदयपुर, राजस्थान में एक दिवसीय विज्ञान आउटरीच कार्यक्रम, प्रकार: मौखिक प्रस्तुति, 2020-04-03
15. “सौर सक्रियता एवम अंतरिक्ष मौसम” : डॉ. गिरजेश गुप्ता, उदयपुर सौर वेधशाला राष्ट्रीय विज्ञान दिवस कार्यक्रम, के दौरान नवोदय विद्यालय (शिक्षा विभाग, भारत सरकार के अधीन एक स्वायत्त संस्था), मावली, उदयपुर, राजस्थान में एक दिवसीय विज्ञान आउटरीच कार्यक्रम, प्रकार: मौखिक प्रस्तुति, 2020-04-03
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52. “मास्ट डाटा अवलोकन एवम डाटा संग्रहण वेब-पेज” सुश्री अनिशा कुल्हरी, उदयपुर सौर वेधशाला में हिंदी पखवाड़ा के अंतर्गत आयोजित हमारा कार्य प्रतियोगिता, प्रकार: मौखिक प्रस्तुति, 2019-09-28
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# Student Training

**Astronomy and Astrophysics**

1. Ms. Swarali Patil, IISER Thiruvannanthapuram, “Exploring the Properties of Star Cluster NGC 1893 with GAIA”, from May 2019 to July 2019, [Supervisor: Dr. Manash Ranjan Samal].
2. Mr. Manish Chauhan, IISER Thiruvannanthapuram, “Jet-bearing YSOs in Vulpecula OB associ-ation”, from August 2019 to September 2019, [Supervisor: Dr. Manash Ranjan Samal].
3. Mr. Jitesh Kumar Tehalramani, Madhav University, “Proving Sequential Star Formation in the Shells of Expanding Bubbles”, from January 2020 to May 2020, [Supervisor: Dr. Manash Ranjan Samal].
4. Mr. B. S. Bharath Saiguhan, Indian Institute of Space Science and Technology, Thiruvananthapuram, “Active Galactic Nuclei Properties, Data Reduction and Analysis”, from May 2019 to July 2019, [Supervisor: Dr. Sachindra Naik].
5. Ms. Priya B. Shanmuga, Manipal University, “Radio Study of Active Galactic Nuclei”, from May 2019 to July 2019, [Supervisor: Dr. Veeresh Singh].
6. Mr. Sattwik Sadhu, NIT, Rourkela, “Study of Solar Coronal Magnetic Field Extrapolation”, from May 2019 to July, 2019, [Supervisor: Aveek Sarkar].
7. International/National student participants of COSPAR capacity building workshop, “Broadband Spectral and Timing Studies with Astrosat, Chandra and XMM-Newton” at IISER, Mohali, [Project Supervisor: Dr. Sachindra Naik]

**Solar Physics**

8. Bhaskar Srinivasan, UN School of Space Science (CSSTEAP), PRL, “Dynamics of Alfven waves”, from January 2019 to April 2019, [Supervisor: Ramit Bhattacharyya].
9. Baburam Sharma, UN School of Space Science (CSSTEAP), PRL, “Study of Solar origin of low frequency radio burst observed by e-CALLISTO network”, from January 2019 to April 2019, [Supervisor: Bhuwan Joshi].

**Planetary Sciences**

10. C Hephzibah, College of Engineering - Guindy, Chennai, “Classification of lunar craters based on their floor subsidence”, from May 2019 to July 2019, [Supervisor: A. Bhardwaj].
11. Shreeyesh Biswal, IISER Pune, “Impact of X class solar flares on the TEC of the ionosphere”, from May 2019 to July 2019, [Supervisor: A. Bhardwaj].
12. Jyoti Singh, Banasthali Vidyapith, Jaipur, Rajasthan, “Study of Micrometeorite Ablation in Martian Atmosphere”, from May 2019 to July 2019, [Supervisor: J. P. Pabari].
13. Love Bansal, Amity University, Noida, “Instrumentation for Planetary Lightning”, from May 2019 to July 2019, [Supervisor: J. P. Pabari].
14. Gagan Dhote, Barkatullah University, Bhopal, “Lightning data analysis”, from January 2020 to June 2020, [Supervisor: J. P. Pabari].
15. Rashmika D. Chaudhari, Hemchandracharya North Gujarat University, Patan, “Development and testing of analog electronics for lightning detector”, from November 2019 to May 2020, [Supervisor: J. P. Pabari].
16. Niki J. Panchal, Hemchandracharya North Gujarat University, Patan, “Development and testing of analog electronics for lightning detector”, from November 2019 to May 2020, [Supervisor: J. P. Pabari].
17. Jyoti Singh, Banasthali Vidyapith, Jaipur, Rajasthan, “Study of Micrometeorite Ablation in Martian Atmosphere”, from November 2019 to November 2019, [Supervisor: J. P. Pabari].
18. Suchika Yadav, Banasthali Vidyapith, Jaipur, Rajasthan, “Revisiting Venusian Lightning Phenomenon”, from August 2019 to May 2020, [Supervisor: J. P. Pabari].
19. Jay M. Jakhariya, GTU, Ahmedabad, “Comparative Analysis of Dust Detector Configuration and FE Electronics”, from October 2019 to June 2020, [Supervisor: J. P. Pabari].
20. Harsh V. Parmar, GTU, Ahmedabad, “Investigation of Hypervelocity Dust and Processing Electronic For It’s Detection”, from August 2019 to June 2020, [Supervisor: J. P. Pabari].
21. V. R. Dinesh Kumar, BITS Pilani, Hyderabad Campus, “Effect of Medium on EM Wave Propagation: With Focus on Venus Dayside”, from May 2019 to June 2019, [Supervisor: J. P. Pabari].
22. Dipti Yadav, Banaras Hindu University (BHU), Varanasi, “Energy harvesting from lunar surface”, from May 2019 to June 2019, [Supervisor: J. P. Pabari].
23. Magendra S., IIT Delhi, “Range and Azimuth Direction Estimation in a 2D WSN Using a Single Localized and Oriented Node”, from May 2019 to June 2019, [Supervisor: J. P. Pabari].
24. Ramkumar P. R., Anna University, Chennai, “Modelling a device for capturing interplanetary dust particles using magnetic mirroring technique”, from May 2019 to June 2019, [Supervisor: J. P. Pabari].
25. Riekshika Sanwari, National Institute of Technology, Patna, “Venus Lightning: Data Analysis with Mathematical Approach”, from May 2019 to June 2019, [Supervisor: J. P. Pabari].

26. Avantika V. Gupta, Charotar University of Science and Technology, Changa, Nadiad, “Venus Lightning: Design and Testing of Processing Electronics for Hypervelocity Dust Detection”, from January 2020 to April 2020, [Supervisor: J. P. Pabari].
27. Shubhabroto Mukherjee, National Institute of Technology, Tiruchirappalli, “Data Analysis of Galileo and Ulysses Dust Detector”, from December 2019 to January 2020, [Supervisor: J. P. Pabari].
28. Chandani P. Pabari, St. Xaviers College, Ahmedabad, “Interplanetary Dust Distribution Derived from Galileo DDS Measurements”, from May 2019 to June 2019, [Supervisor: J. P. Pabari].
29. Heena H. Dabhi, Gujarat University, Ahmedabad, “Mineral Composition Mapping of Von Karman using Reflectance Spectroscopy”, from May 2019 to July 2019, [Supervisor: M. Bhatt].
30. Prateek Tripathi, Indian Institute of Technology, Roorkee, “Spectral analysis of Reiner Gamma, Gerasimovich and mare Ingenii swirls”, from May 2019 to June 2019, [Supervisor: M. Bhatt].
31. Raj Patel, Indian Institute of Technology, Guwahati, “Mons Malapert: A Potential Site for Lunar Outpost”, from October 2019 to May 2020, [Supervisor: M. Bhatt].
32. Krunal Mehta, Indus University, Ahmedabad, “Development of a framework for complete characterization of OH/H2O of Lunar surface using hyperspectral data ”, from January 2020 to May 2020, [Supervisor: M. Bhatt].
33. Deepali Singh, JNU Delhi, “Study of the biosignature preservation potential within the Mars 2020 landing site”, from May 2019 to June 2019, [Supervisor: R. K. Sinha].
34. Vidhesh Shukla, Wadia Institute of Himalayan Geology, Dehradun, “Glaciation on Mars: Geological insights from the Erebus Montes region in the mid- latitudes”, from May 2019 to June 2019, [Supervisor: R. K. Sinha].
35. Saurav Sharma, IIT Roorkee, “Development of a prototype sensor for thermal conductivity measurements in Lunar analogous samples.”, from June 2019 to July 2019, [Supervisor: K. Durga Prasad].
36. Ishika Bhattacharya, IIT Dhanbad, “Understanding and Reanalysis of Lunar Seismic Data”, from May 2019 to July 2019, [Supervisor: K. Durga Prasad].
37. Inturi Srivani, Nagarjuna University, “Variation of electron temperature, electron density in Martian ionosphere”, from May 2019 to July 2019, [Supervisor: K. Durga Prasad].
38. Riddhish Soni, IIRS, Dehradun, “Evaluation of Lunar subsurface temperature using Chang’e data”, from May 2019 to July 2019, [Supervisor: K. Durga Prasad].
39. Nilkantha Gholap, Fergusson College, Pune, “Lab Based Quantification of Liquid Water in Soil”, from May 2019 to July 2019, [Supervisor: K. Durga Prasad].
40. Batbayaraa, Mongolian Academy Of Sciences, Ulaanbaatar, Mongolia, “Investigation of Thermophysical Properties of Lunar Analogues by Laboratory Measurements”, from January 2019 to April 2019, [Supervisor: K. Durga Prasad].
41. Swatantra Kumar, IIT Kharagpur, “Study of Thermophysical properties of Moon and Mars”, from June 2019 to July 2019, [Supervisor: Chandan Kumar].
42. Unnati Raje Singh, Banasthali University, “Back-End and Processing electronics for plasma instrumentation for planetary missions”, from January 2019 to June 2019, [Supervisor: Chandan Kumar].
43. Payal Shekhawat, Rajasthan University, “Study and design aspects of nephelometer for planetary atmospheres”, from May 2019 to June 2019, [Supervisor: S. K. Mishra].

**Space and Atmospheric Sciences**

44. Mr. Shreeyesh Biswal, IISER-Pune, “TEC of the ionosphere: theory and case studies”, from May 2019 to July 2019, [Supervisor: D. Chakrabarty].
45. Mr. Rijul Dimri, NIT-Rourkela, “Langmuir probe for ionospheric studies: Geometry and Theories”, from May 2019 to July 2019, [Supervisor: D. Chakrabarty].
46. Mr. Jacob Sebastian, IIST, BS (Physical Sciences), “The day sky spectra”, from June 2019 to July 2019, [Supervisor: D. Pallamraju].
47. Ms. Dhanashree Gaidhane, Madurai Kamraj University, “Study of ionosphere over Ahmedabad”, from May 2019 to July 2019, [Supervisor: D. Pallamraju].
48. Mr. Tej Joshi, MTech, Mechanical Engineering, Pandit Deendayal Petroleum University, “Sun tracking and stabilization for high altitude balloon payload”, from Oct 2019 to June 2020., [Supervisor: H. Gadhavi].
49. Mr. Kashyap Patel, Gujarat University, “Climate Change Impacts Management”, from 27 November 2019 to Present., [Supervisor: Lokesh Kumar Sahu].
50. Mr. Dhananjay Trivedi, (M. Sc. Tech) from Department of Geophysics, Banaras Hindu University (BHU), Varanasi, “Evaluation of model reanalysis over Indian region”, from May to July 2019, [Supervisor: Narendra Ojha].
51. Mr. N Sasikaran Nirmal Rajan, University of Madras, “An analysis on total electron content and its variation in ionosphere”, from May 2019 to July 2019, [Supervisor: Ravindra Pratap Singh].
52. Ms. Sumitra Sharma, University of Rajasthan, “Study of Atmospheric Boundary Layer over Ahmedabad”, from May 2019 to July 2019, [Supervisor: Som Kumar Sharma].
53. Mr. Hrishikesh Dubey, Institute for Excellence in Higher Education, Bhopal, “Study of atmospheric parameters using MICROTOP II SUNPHOTOMETER”, from Jan 2020 to May 2020, [Supervisor: Som Kumar Sharma].

**Geosciences**

54. Ankit Patel, Atmospheric Science Dept., Central University of Rajasthan, “Characterization of atmospheric aerosol over the remote site, Port Blair”, from May 2019 to July 2019, [Supervisor: N. Rastogi].
55. Jay Dave, Analytical Chemistry, Gujarat University, Ahmedabad, “Characteristics of brown carbon aerosol, and Organic aerosol Characterization”, from September 2018 to May 2020, [Supervisor: N. Rastogi].
56. Ayushi Mittal, Department of Earth Sciences, Indian Institute of Technology (IIT) Roorkee, “The Raman Spectroscopy of inorganic minerals of Piplia Kalan Achondrite meteorites”, from April 2019 to May 2020, [Supervisor: A.D. Shukla].

57. Riddhi Siddhipura, Analytical Chemistry, Gujarat University, Ahmedabad, “Quantification and behavior of a few elements from lake sediments from Ladakh Himalaya”, from May 2019 to January 2020, [Supervisor: A.D. Shukla].
58. Shreya Mehta, Indian Academy Sciences summer research fellow, “Uncertainties in palaeo-salinity estimates”, from May 2019 to July 2019, [Supervisor: A. Singh].
59. Harshit Raj, intern, Delhi University, “Mixed layer depth estimates”, from May 2019 to July 2019, [Supervisor: A. Singh].

**Theoretical Physics**

60. Drona Vatsyayna, University of Delhi, “Thermal Leptogenesis”, from August 2019 to December 2019, [Supervisor: S. Goswami].
61. G. Greeshma, Central University of Tamil Nadu, “Field Theories and Scattering Cross-sections”, from May 2019 to July 2019, [Supervisor: N. Mahajan].
62. P. Govindrajan, Indian Institute of Science Education and Research, Thiruvanantapuram, “Relativistic Quantum Mechanics - The Dirac Equation”, from May 2019 to July 2019, [Supervisor: K. M. Patel].
63. Minaxi Moun, Indian Institute of Science Education and Research, Mohali, “Renormalization Group Equations in the Standard Model and Beyond”, from August 2018 to April 2019, [Supervisor: K. M. Patel].
64. Ravneet S. Bedi, Indian Institute of Science Education and Research, Mohali, “Continuum Clockwork as a De-constructed Extra Dimension”, from August 2018 to April 2019, [Supervisor: K. M. Patel].

**Atomic, Molecular and Optical Physics**

65. Sachin Joshi, MSU Baroda, “Multispectral fading studies in Feldspar”, from May 2019 to July 2019, [Supervisor: Naveen Chauhan].

# Division Visitor Details

**Astronomy and Astrophysics**

1. Dr. Bidya Binay Karak, IIT, BHU, “for collaborative research work”, from 14-07-2019 to 21-07-2019.
2. Dr. Prithish Halder, Assam University, Silchar, “to deliver area seminar”, from 13-04-2019 to 19-04-2019,[Seminar : “A comprehensive study of comet dust at different heliocentric distances for varying radiation pressure”].
3. Prof. T. Sivarani, Indian Institute of Astrophysics Bangalore, “to deliver colloquium ”, from 10-06-2019 to 11-06-2019.
4. Dr. Sunil Chandra, Centre for Space Research, North-West University, South Africa, “for collaborative research work”, from 13-10-2019 to 14-10-2019.
5. Dr. Sunil Chandra, Centre for Space Research, North-West University, South Africa, “to deliver area seminar”, from 22-11-2019 to 22-11-2019,[Seminar : “Challenges in the calibration of astronomical X-ray instruments”].
6. Dr. Sunil Chandra, Centre for Space Research, North-West University, South Africa, “for collaborative research work ”, from 06-01-2020 to 09-01-2020.
7. Dr. Ramkesh Yadav, National Astronomical Research Institute of Thailand, “for collaborative research work”, from 15-03-2019 to 15-04-2019.
8. Mr. Supriyo Ghosh, Satyendra Nath Bose National Centre for Basic Sciences, Kolkata, “to deliver area seminar”, from 08-05-2019 to 12-05-2019,[Seminar : “Spectroscopic and photometric study of cool and evolved stars”].
9. Dr. Samyaday Choudhury, Macquarie University Sydney Australia, “to deliver area seminar”, from 23-12-2019 to 25-12-2019,[Seminar : “Sparse star clusters and photometric metallicity maps of the Magellanic Clouds”].

**Solar Physics**

10. Mr. Suvadip Sinha, CESSI, Indian Institute of Science Education and Research, Kolkata, “Collaborative work”, from 01-06-2019 to 28-06-2019,[Seminar : “Tracking of solar eruptive filaments and finding the temporal connection with associated flare-CME events”].
11. Dr. Wahab Uddin, Aryabhatta Research Institute of Observational Science (ARIES), Nainital, Uttarakhand, “Calibration of Fabry-Perot based instrument with MAST ”, from 18-09-2019 to 20-09-2019,[Seminar : “Solar Physics at ARIES Nainital”].
12. Dr. Anil Kumar, Indian Institute of Remote Sensing, Dehradun, “Collaborative project”, from 12-12-2019 to 13-12-2019,[Seminar : “Machine-learning and its application in remote sensing data classification”].
13. Ms. Pooja Setia, Kumaun University, Nainital, “Collaborative work”, from 18-01-2020 to 31-01-2020,[Seminar : “Development of a confined circular-cum-parallel ribbon flare and associated pre-flare activity”].

**Space and Atmospheric Sciences**

14. Ms. Lakhima Chutia, Centre for Atmospheric Studies, Dibrugarh University, Assam, India, “for collaborative research on the distribution of sulfur dioxide over Indian region”, from 23-09-2019 to 25-09-2019,[Seminar : “Atmospheric composition over south Asia: model simulation versus observations”].
15. Dr. Tabish Umar Ansari, Postdoctoral researcher at School of Physics, National University of Ireland-Galway, Ireland, “To deliver area seminar”, from 09-01-2020 to 10-01-2020,[Seminar : “Aerosol formation in urban environment: Lessons learnt from modelling winter haze in Beijing”].
16. Mr. Shreeyesh Biswal, BS-MS, 4th year student at IISER, Pune, “to complete the research work on solar flares in solar cycle 24 and its impact on TEC over the anomaly crest region”, from 11-01-2020 to 21-01-2020.
17. Ms. Komal Kumari, Graduate student at the Department of Physics and Astronomy, Clemson University, Clemson, “to deliver division seminar”, from 13-01-2020 to 13-01-2020,[Seminar : “QBO, ENSO and Solar Cycle Effects in Short-term Non-migrating Tidal Variability on Planetary Wave Timescales from SABER - An Information-Theoretic Approach”].

**Theoretical Physics**

18. Dr. Pankaj Bhalla, Visiting fellow, University of new South Wells, Sydneey, Australia, “Seminar and Scientic discussions”, from 27-02-2020 to 28-02-2020,[Seminar : “Resonant photovoltaic effect in doped magnetic semiconductors”].
19. Dr. Tuhin Mallik, Dept. of Physics, BITS Pillani, Goa Campus, Goa, “Collaborative work”, from 01-02-2020 to 15-02-2020.
20. Dr. Bharat Kumar, Center for Computational Sciences, Tsukuba, Japan, “Seminar and discussions”, from 24-02-2020 to 28-02-2020,[Seminar : “Constraints on the moment of inertia of neutron-star/pulsars”].
21. Professor Sanatan Digal, Institute of Mathematical Sciences, Chennai, “Seminar”, from 29-01-2010 to 01-02-2020,[Seminar

: "$Z_N$ Symmetry and confinement-deconfinemt transition in SU(N) + Higgs Theories at finite Temperature"].

22. Dr Anushree Ghosh, University of Padova, Italy, "Seminar and discussions", from 11-01-2020 to 15-01-2020,[Seminar : "Reconstruction @Minerva: From traditional to machine learning techniques"].
23. Dr Avdesh Kumar, Institute of nuclear Physics, University of Krakow, Poland, "Seminar and discussions", from 31-12-2019 to 05-01-2020,[Seminar : "Hydrodynamics of spin polarised fluids"].
24. Dr Newton Nath, PDF, Institute for High Energy Physics, Beijing, chin, "Seminar and discussions", from 10-10-2019 to 15-10-2019,[Seminar : "Recent Developments in $\mu$ - $\tau$ Symmetry"].
25. Dr. S. Mazumder, PDF, Department of Physics IIT Roorkee, "Collaborative work", from 08-10-2019 to 23-10-2019.
26. Dr. Ranjan Laha, CERN, Theoretical Physics division, Switzerland, "Seminar and discussions", from 26-08-2019 to 29-08-2019,[Seminar : "Search for dark matter in astroparticle physics"].
27. Dr. Ranjita Mohapatra, Department of Physics, IIT Bombay, "Collaborative work", from 26-04-2019 to 15-05-2019.
28. Dr. Diganta Das, INSPIRE Faculty, Dept. of Physics and Astrophysics, Univ. Delhi, "To give seminar on recent work and discuss with group members", from 12-11-2019 to 16-11-2019,[Seminar : "Improving the Standard Model prediction of the muon anomalous magnetic moment through high precision determination of the pion electromagnetic form factor and pion charge radius"].
29. Dr. Tanmoy Modak, National Taiwan Univ. Taipei, Taiwan, "Visited to give a seminar and interact with group members ", from 06-02-2010 to 09-02-2012,[Seminar : "Signatures of extra Yukawa couplings at the LHC and beyond"].
30. Dr. Abhishek Iyer, Groupe de Physique Thorique, IP2I - Universit Lyon 1, Cedex, "Wanted to come for a day to meet and discuss with group members", from 05-02-2020 to 07-02-2020.
31. Prof. Rahul Sinha, Institute of Mathematical Sciences, Chennai, "External Examiner for Ms. Bharti Kindra's Viva voce examination", from 17-01-2020 to 17-01-2020.
32. Bharti Kindra, Dept. of Physics and Astrophysics, Univ. Delhi, "PhD viva voce at IIT Gandhinagar", from 16-01-2020 to 22-01-2020.
33. Dr. Kinjalk Lochan, Indian Institute of Science Education and Research, Mohali, "For seminar and collaborative work", from 22-07-2019 to 26-07-2019,[Seminar : "Quantum Fields in Cosmology : The omnipresent de Sitter and theinvariantvacuumnoise"].
34. Himanshu Swami, Indian Institute of Science Education and Research, Mohali, "For collaboration on ongoing project", from 25-07-2019 to 08-08-2019.

**Atomic, Molecular and Optical Physics**

35. Amala Varghese, Christ College, Kerala, "Learning basics of luminescence dating", from 01-04-2019 to 30-04-2019.
36. Komal Sharma, MSU Baroda, "Finishing thesis work", from 01-04-2019 to 30-04-2019.
37. Biraj Borgohain, IIT Mumbai, "Paper writing and discussion", from 22-04-2019 to 26-04-2019.
38. Komal Sharma, MSU Baroda, "Thesis writing", from 01-05-2019 to 02-07-2019.
39. Belligraham Narzary, IISER Kolkata, "Learning fading corrections", from 24-05-2019 to 27-05-2019.
40. Anil Devara, MSU Baroda, "Luminescence dating of samples", from 09-07-2019 to 30-08-2019.
41. satyabrata Das, Wadia institute, "Luminescence dating of samples", from 25-07-2019 to 08-08-2019.
42. Anushka Vashistha, IIT Gandhinagar, "Mtech disertation", from 09-08-2019 to 20-08-2019.
43. Sila Tripathy, NIO, Goa, "Luminescence dating of pottery samples", from 13-10-2019 to 20-10-2019.
44. Saptarshi Dey, IIT GANDHINAGAR, "Luminescence dating and learning", from 24-09-2019 to 08-10-2019.
45. Dr. P Morthekai, BSIP, Lucknow, "Secondary calibration of alpha source for his laboratory", from 20-10-2019 to 23-10-2019.
46. Neha Jitkar, Ferguson college Pune, "Measurements of samples", from 05-11-2019 to 15-11-2019.
47. Shubham Gavane, D. Y. Patil College, Pune, "Luminescence dating of samples", from 05-02-2020 to 15-02-2020.
48. Ms. Sumeet Kaur, Department of Physics, Guru Nanak Dev University,Punjab, "Ms. Sumeet Kaur worked on a project on quantum computation. We (with B.K.Sahoo) have initiated this research work at PRL through this project, which will be the first such application in India. A manuscript is under preparation based on the work she did at PRL during her tenure. ", from 02-09-2020 to 02-06-2020.

# Astronomy and Astrophysics

**Solar X-ray Monitor on-board Chandrayaan-2: Calibration, Data Analysis, and POC operations**

Solar X-ray Monitor (XSM), designed and developed at PRL, is one of the scientific instruments on-board the Chandrayaan-2 orbiter. The main objective of XSM is to carry out X-ray spectral measurements of the sun in 1 - 15 keV energy range. In order to estimate the incident X-ray spectrum from the Sun using observations with XSM, it is essential to calibrate the instrument and derive an accurate response matrix. Extensive calibration experiments were carried out on ground for XSM to obtain gain correction factors as a function of operating conditions, spectral redistribution function, collimator response and effective area, dead time and pileup characteristics, and spectral characteristics with incident flux. As an example, Figure no. 1 shows the XSM spectra for three mono-energetic X-ray lines from beam-lines of Indus-2 synchrotron facility at RRCAT. Over plotted on the data are the best fit models of empirical spectral redistribution functions that take into account the photo-peak, escape peak, low energy tail due to incomplete charge collection, and shelf component arising from electron escape. Fitted model parameters for multiple mono-energetic lines thus obtained are used to generate the redistribution matrix of XSM. This redistribution matrix along with the effective area are to be used in the spectral analysis of XSM observations.

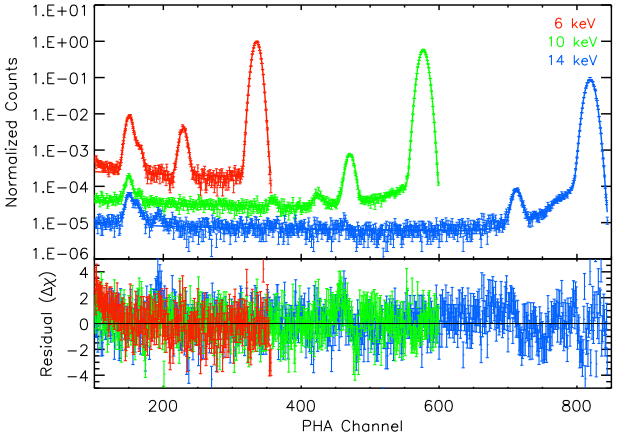


Figure no. 1: XSM spectra for three mono-energetic lines fitted with the spectral redistribution model. The bottom panel shows the residuals.

The adequacy of ground calibration of the gain parameters and spectral redistribution are verified during the in-flight operations with the observations of the on-board calibration source. Further refinement of the angular response and effective area are carried out utilizing the observations of the sun at different angles with respect to the bore-sight of XSM. Calibration data obtained from ground and in-flight are incorporated into the calibration database of XSM which is accessed by the analysis procedures during data processing. Data from Chandrayaan-2 are downloaded from the spacecraft over India Deep Space Network (IDSN) and Deep Space Network (DSN) ground stations, and payload-wise segregation and level-0 processing is carried out at Indian Space Science Data Center (ISSDC), Bangalore. XSM level-0 data is fetched from ISSDC to the Payload Operations Center (POC) at PRL, where the XSM Data Analysis Software (XSMDAS) carries out higher level data processing. The XSMDAS software consists of a collection of modules, each dedicated to a specific function. Data downloaded over multiple-orbits are combined together to provide day-wise merged raw data along with auxiliary data and calibrated products from standard processing. The data processing chain at XSM POC is now fully operational and automated, generates quick look plots, and uploads the higher level data back to ISSDC. Data products archived in PDS4 compliant format will be made available publicly after a lock-in period from ISSDC.

**(Mithun N. P. S., S. Vadawale, M. Shanmugam, A. Patel, N. Singh, S. Kumar, N. K. Tiwari, H. K. Adalja, S. K. Goyal, T. Ladiya)**

**X-ray Spectroscopy of the Sun with Chandrayaan-2 Solar X-ray Monitor**

Solar X-ray Monitor (XSM) offers disk integrated soft X-ray spectroscopy of the sun with a time cadence of one second and the highest spectral resolution for a wide-band X-ray spectrometer for solar observations. Such broad-band X-ray spectroscopic studies of the sun complement the observations with the existing wide-band integrated X-ray imagers and narrow band high resolution spectrographs. After the initial commissioning phase, XSM has begun regular observations of the sun in early September, 2019. During this period, solar activity was at its minima with long duration without any active regions present. Despite the very low activity, XSM with its high sensitivity could measure the solar X-ray spectrum during this period. With background measurements and solar observations, XSM is shown to be sensitive to solar activity as low as two orders of magnitude below GOES flare class A. The first B class flare was detected with XSM on 30 September. Figure no. 2 shows the light curve, flux, and dynamic spectrum of the sun around this period measured with XSM. The Figure no. 2 shows the sensitivity of XSM to detect solar activity much weaker than A-class and the ability to measure the spectral variability during solar flares. Detailed spectral analysis of such events would provide insights into the variations in elemental abundances in corona. XSM also

has detected several sub-A class flare events like the few seen in the Figure no. 2 allowing a detailed study of energetics and addressing the contribution of weak flares in the coronal heating.

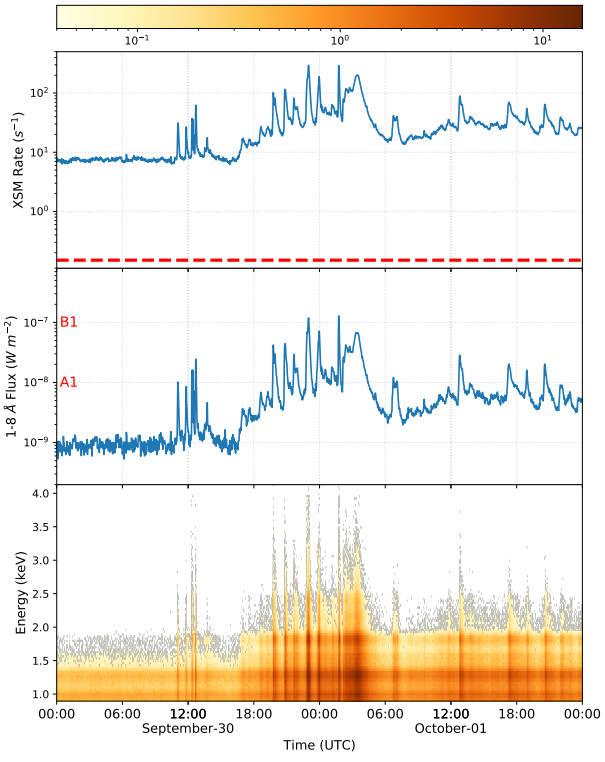


Figure no.2: Light curve (top), X-ray flux in 1-8 (1.55-12.4 keV) range (middle), and dynamic spectrum (bottom) of the sun during two days as measured with XSM. The red dashed line in the top panel shows the typical background rate in XSM, demonstrating the sensitivity of the instrument.

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

### Elemental abundance estimation with Alpha Particle X-ray Spectrometer: An empirical approach

Experiments for in-situ measurements of elemental abundances have been an integral part of planetary rover missions. One of the widely used techniques involves measurement of the X-ray spectrum of the sample after exciting it with particle and X-ray radiation. Alpha Particle X-ray Spectrometer (APXS) instrument flown on the rover of Chandrayaan-2 mission intended to perform such an experiment on the southern region of the Moon. APXS provides measurement of the X-ray spectrum of the sample where the fluorescence lines of various elements are distinctly identified, such as that shown in Figure no. 3. In order to derive the elemental abundances from the measured spectrum, we developed an empirical methodology. APXS spectra are obtained for a suite of Geo-chemical reference materials (GRM) with known composition that span the expected range of abundances of all major elements on the highland regions on the moon. These spectra are fitted in XSPEC taking into account the spectral response of the detector to obtain the intensities of the elemental lines.

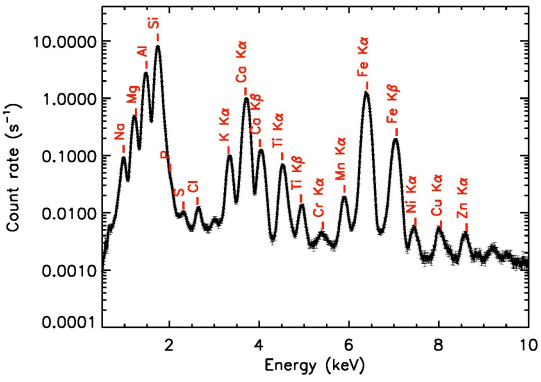


Figure no. 3: APXS spectrum of one of the geochemical reference samples W-2A. Spectrum up to 10 keV is shown with the lines of various elements identified.

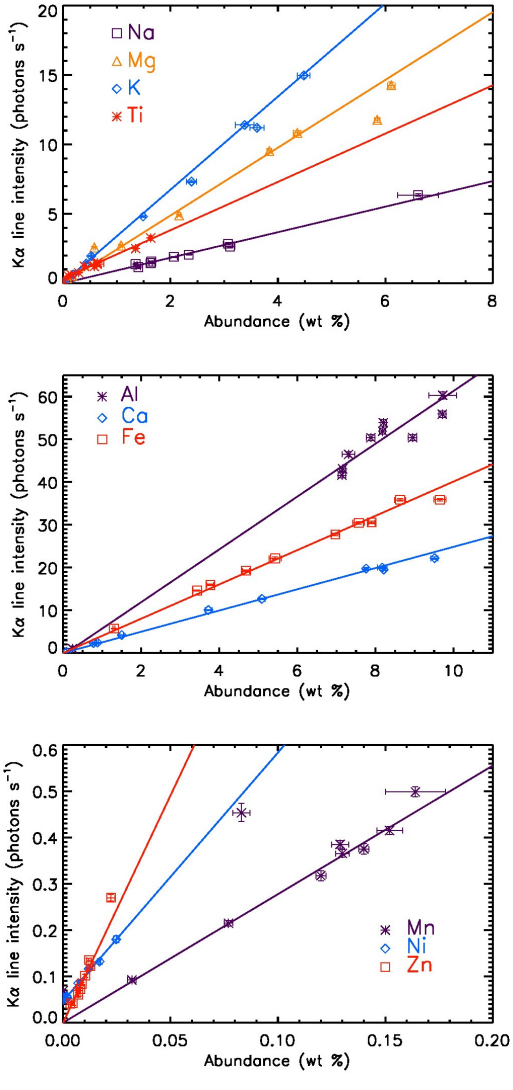


Figure no. 4: Elemental abundance - line intensity correlations for APXS at the nominal target distance of 55 mm. Matrix correction, as described in the text, is applied to the measured line intensities. Solid lines are the result of least square fitting to the respective data points.

The line intensity for each element depends not just on the concentration of that element, but also of the others. Measured line intensities are scaled with the attenuation coefficient of the sample at the line energy to take into account this matrix effect. Correlations are then obtained between the line intensities and abundances which are shown in figure no. 4. An interactive algorithm is employed to obtain the abundances of unknown samples from their measured APXS spectra using the correlation parameters obtained from the GRMs. It is shown that APXS can estimate the abundances of all major elements on the moon with an uncertainty of less than 10% of the abundance value itself. Simulations show that elements present having a concentration of more than 0.2% can be detected to $3\sigma$ level with APXS observations of half an hour. The APXS instrument will also be included in the lunar rover of the upcoming Chandrayaan-3 mission and the same methodology will be applicable for deriving the elemental abundances of the lunar surface with Chandrayaan-3 APXS.

doi : https://doi.org/10.1016/j.pss.2020.104923

**(N. P. S. Mithun, S. Vadawale, M. Shanmugam, A. Patel, N. Singh, S. Kumar, N. K. Tiwari, S. K. Goyal, A. B. Sarbadhikari, G. Arora, Y. Srivastava, H. K. Adalja, T. Ladiya, D. K. Painkra, S. B. Banerjee, V. R. Patel and A. Bhardwaj)**

**The response of the terrestrial magnetosphere to the long term decline in solar photospheric magnetic fields**

A detailed analysis of the response of the terrestrial magnetosphere has been carried out by studying the extent and shape of the Earths magnetopause and bow shock over the past four solar cycles. Work carried out by us earlier has shown that both solar magnetic fields and solar wind micro-turbulence levels have been steadily decreasing since around 1995, a period of well over two 11 year solar cycles. In a detailed study, we have examined the response of the terrestrial magnetosphere to this long-term and steady declining trend that has been continuing to the present. We have estimated the sub-solar stand-off distance of the terrestrial magnetopause and bow shock, and the shape of the magnetopause using numerical as well as empirical models. The computed magnetopause and bow shock stand-off distances have been found to be increasing steadily since around the mid-1990s, consistent with the steady declining trend seen in solar magnetic fields and solar wind micro-turbulence levels. Similarly, we find an expansion in the shape of the magnetopause since 1996. In addition, we have been able to make a prediction of the shape of the magnetopause in 2020, the expected minimum of the current solar cycle 24. Importantly, we also find two instances between 1968 and 1991 when the magnetopause stand-off distance dropped to values close to 6.6 earth radii, the geostationary orbit, for duration ranging from 9-11 hours and one event in 2005, post 1995 when the decline in photospheric fields began. This is a very important finding as it represents a clear and present danger to our satellite systems in the event of a large CME impact, especially given the fact that very large CMEs have been known to occur in weak solar cycles.

This work has been done in collaboration with Dr. S. K. Bisoi from National Astronomical Observatories, CAS, Beijing, China.

doi : https://doi.org/10.1029/2019JA026616

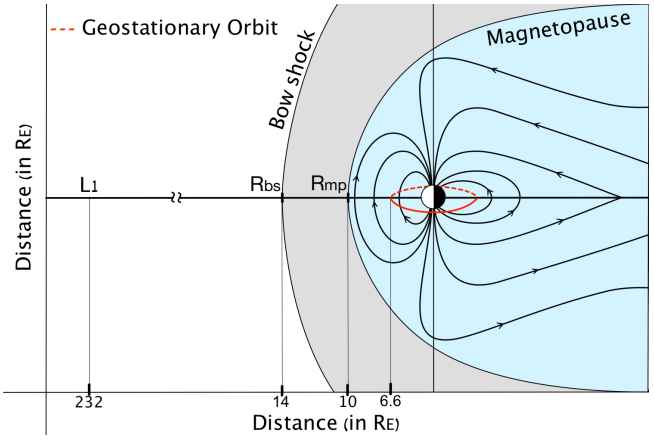


Figure no. 5: A schematic of the stand-off distance of the MP (Rmp) and BS (Rbs) in the GSM coordinate system. The dotted red circle is the geostationary orbit at 6.6 earth radii (RE).

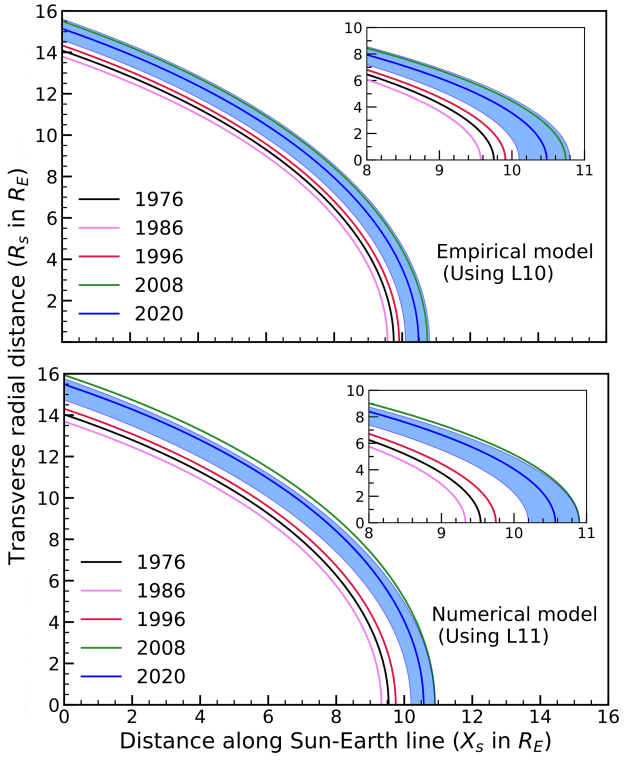


Figure no. 6: One year averaged MP shapes at solar minima for solar cycles 20 - 24 shown by plots of transverse radial distance of MP, Rs against the extent of the MP along the sun-earth line, Xs. The blue curve is the forecast of the MP shape at the expected minimum of cycle 24 in 2020, with a shaded blue band of 95% confidence interval. Insets are zoomed versions of the MP shape.

**(P. Janardhan, M. Ingale, and S. K. Bisoi)**

**Global solar magnetic field during the past four solar cycles inferred using potential-field source-surface extrapolations**

While direct measurements of solar photospheric magnetic fields can be made, the magnetic fields in the solar corona are very difficult to measure directly. The relation between the photospheric magnetic fields and those in the low corona/solar wind are therefore not straightforward. To gain insights into this relationship and to get an idea of the fields in the corona from 2.5 to 10 solar radii, we have used potential-field source-surface (PFSS) extrapolations to deduce global magnetic fields using synoptic magnetograms observed with National Solar Observatory (NSO), Kitt Peak, USA (NSO/KP) and Solar Optical Long-term Investigation of the Sun (NSO/SOLIS) instruments during 1975 2018. From these observations, we have found that, since the mid-1990s, the magnetic field over different latitudes at 2.5 solar radii and 10 solar radii (extrapolated using the PFSS method) has decreased by approximately 11.3% 22.2%, in phase with the declining magnetic fields. These observations emphasize the inter-relationship among the global magnetic field and various turbulence parameters in the solar corona and solar-wind.

This work has been done in collaboration with S. K. Bisoi (National Astronomical Observatories, CAS, China), M. Ingale (IISER Pune), P. Subramanian (IISER Pune), K. Fujiki. (Institute for Space-Earth Environmental Research, Japan), and M. Maksimovic (Observatoire de Paris Meudon France).

doi : https://doi.org/10.1007/s11207-019-1514-7

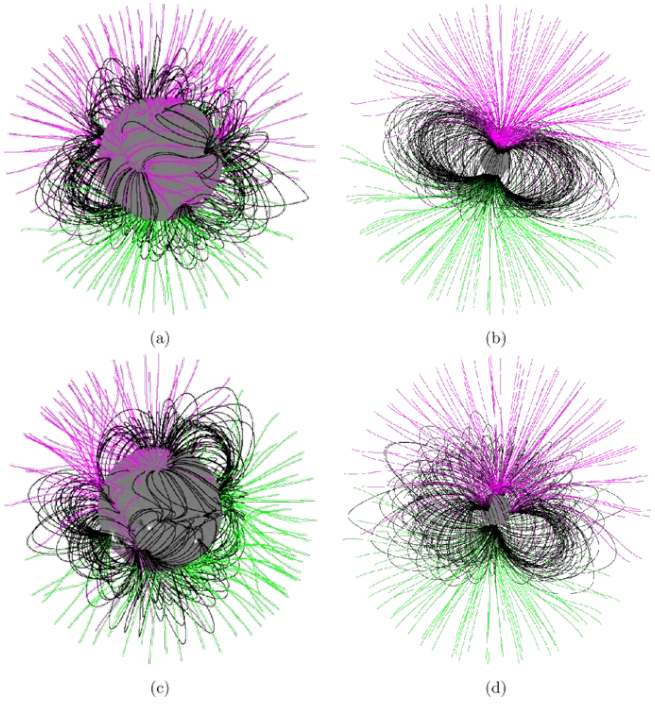


Figure no. 7: Panels (a & b) and (c & d) represent PFSS extrapolated magnetic fields on 2011 August 9 (solar min.) and 2004 July 18 (solar max.), respectively. Panels (a & c) and (b & d) show extrapolated magnetic fields from 1.5 - 2.5 R and 5-10 R , respectively. The central grey disks are magnetograms from NSO/KP or NSO/SOLIS instruments. Black lines are closed field lines, while lines in magenta and green are, respectively, the negative and positive polarities of open fields.

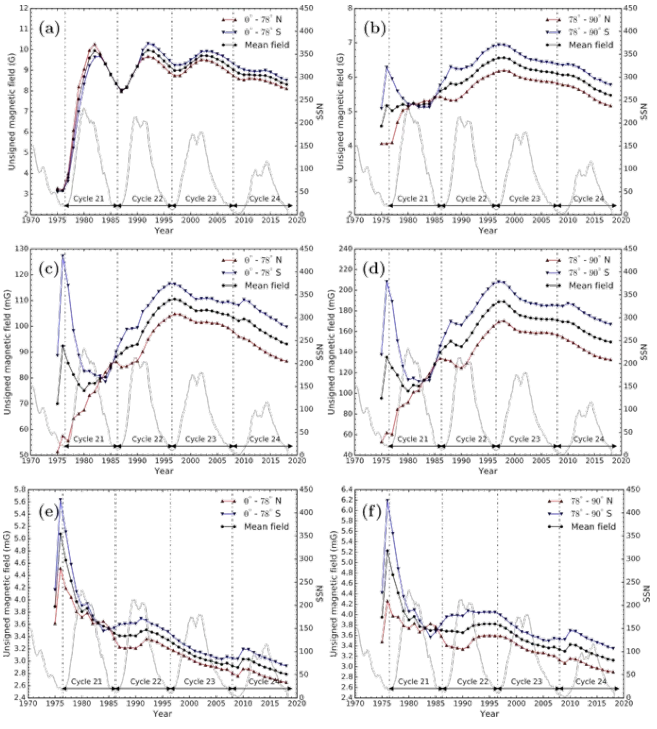


Figure no. 8: The left and right hand panels show the toroidal and mid-latitude fields, respectively. The upward and downward triangles are the northern and southern hemispheric fields while the black circles are the average of the two. The grey curve is the monthly averaged sunspot number. Panels [(a), (b)] are photospheric fields while panels [(c), (d)] and [(e), (f)] are the extrapolated fields at 2.5 R and 10 R,, respectively.

**(P. Janardhan, S. K. Raja., S. K. Bisoi, M. Ingale, P. Subramanian, K. Fujiki., and M. Maksimovic)**

**TOI-503b: PARAS helps to detect the first known brown dwarf-Am star binary system from the NASAs TESS mission**

We have discovered an intermediate-mass transiting brown dwarf, TOI-503b, from NASA's Transiting Exoplanet Survey Satellite (TESS) mission using spectroscopic data from PARAS. The 9 high-resolution spectra acquired from the PARAS spectrograph attached to the 1.2 meter telescope at PRL Observatory, Mount Abu ,during April 06 to April 11, 2019, majorly contributed to the mass-measurement of the brown dwarf. Brown Dwarfs are astrophysical bodies that are neither planets nor stars. Their masses lay between 13 Jupiter mass to 80 Jupiter mass and are extremely rare to find. Less than 25 such astrophysical bodies are known in the Universe whose mass and radii are measured. TOI-503b is the first brown dwarf discovered by TESS, orbiting around a metallic-line A-type star in a 3.6772$\pm$0.0001 days circular orbit. We found that TOI-503b transits its host star in a grazing manner from TESS light curve and estimated the radius of the BD to be 1.34$\pm$0.26 RJ The mass of the brown dwarf was estimated to be 53.7$\pm$1.2 Jupiter Mass (MJ) using the various spectrographs across the globe. The host star has a mass of 1.80$\pm$0.06 solar mass, a radius of 1.7$\pm$0.05 solar radius, an effective temperature of 7650$\pm$160 K, and a relatively high metallicity of 0.61$\pm$0.07 dex. We used stellar isochrones to derive the age of the system to be 180 Myr, which places its age between that of RIK 72b (a 10 Myr old brown dwarf in

the Upper Scorpius stellar association) and AD 3116b (a 600 Myr old brown dwarf in the Praesepe cluster). Given the difficulty in measuring the tidal interactions between brown dwarfs and their host stars, we cannot precisely say whether this brown dwarf formed in-situ or has had its orbit circularised by its host star over the relatively short age of the system. Instead, we offered an examination of plausible values for the tidal quality factor for the star and brown dwarf. TOI-503b joins a growing number of known short-period, intermediate-mass brown dwarfs orbiting main sequence stars, and is the second such brown dwarf known to transit an A star, after HATS-70b. With the growth in the population in this regime, the driest region in the brown dwarf desert (35-55 MJ sin(i)) is reforesting.

This discovery is the joint work of a team from PRL, India, and Centre for Astrophysics, Harvard, USA and KESPRINT Consortium, Europe.

doi : https://doi.org/10.3847/1538-3881/ab7245

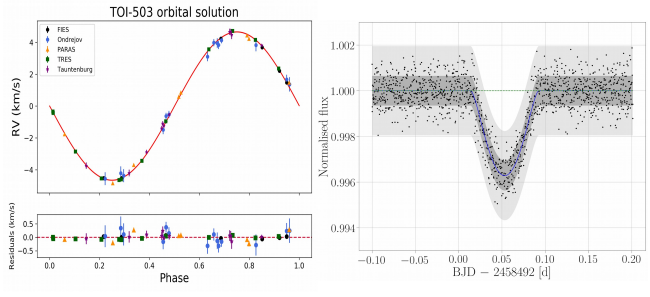


Figure no. 9: Plot of best fitted orbit model from joint RV and transit data fitting. Left panel:- Orbital solution for TOI-503 showing the RV model in red. Right Panel:- The transit light curve of the TOI-503, with best fitted model. The blue line represents the best fitting transit light curve and the green line shows the model without the transit function.

**(R. Sharma and A. Chakraborty)**

### Unveiling molecular clouds toward bipolar HII region G8.14+0.23

Galactic HII regions excited by massive O-type stars are considered as complex physical systems, which are strongly affected by the intense energetic feedback of O-type stars (i.e., stellar wind, ionized emission, and radiation pressure). However, understanding the exact physical mechanism concerning the birth of O-type stars is still being debated. Most recent numerical simulations suggest that bipolar HII regions, powered by O-type stars, can be formed at the interface of two colliding clouds. To observationally understand the birth of O-type stars, we have carried out a detailed multi-wavelength analysis of an area of 1 deg X 1 deg hosting G8.14+0.23 HII region associated with an infrared bipolar nebula (BPN). Based on the radio continuum map, the HII region is excited by at least an O-type star, which is located toward the waist of the BPN. Various observed components related to the site G8.14+0.23 are summarized in Figure no. 10. In Figure no. 10a, the NANTEN2 13CO line data reveal the existence of two extended clouds at [9, 14.3] and [15.3, 23.3] km/s toward the site G8.14+0.23, which are connected in the position-velocity space through a broad-bridge feature at the intermediate velocity range. The cavity or intensity-depression in the blueshifted cloud is highlighted by a broken hexagonal (see figure no. 10b), while the redshifted cloud is shown in Figure no. 10c. Together, Figure no. 10 illustrates a complementary spatial distribution of clouds (i.e., spatial fit between the cavity in the blueshifted cloud and the elongated redshifted cloud; see a solid box in Figure no. 10a). The spatial and velocity connections of the clouds suggest their interaction in the site G8.14+0.23. The analysis of deep near-infrared photometric data reveals the presence of clusters of infrared-excess sources, illustrating ongoing star formation activities in both the clouds. The O-type star is part of the embedded cluster seen in the waist of the BPN, which is observed toward the spatial matching zone of the cavity and the redshifted cloud. The observational results appear to be in reasonable agreement with the numerical simulations of cloud-cloud collision (CCC), suggesting that the CCC process seems to be responsible for the birth of the O-type star in G8.14+0.23.

This work was done in collaboration with H. Sano (Nagoya University, Japan), R. Enokiya (Nagoya University, Japan), K. Tachihara (Nagoya University, Japan), and D. K. Ojha (TIFR, India).

doi : https://doi.org/10.3847/1538-4357/ab1cba

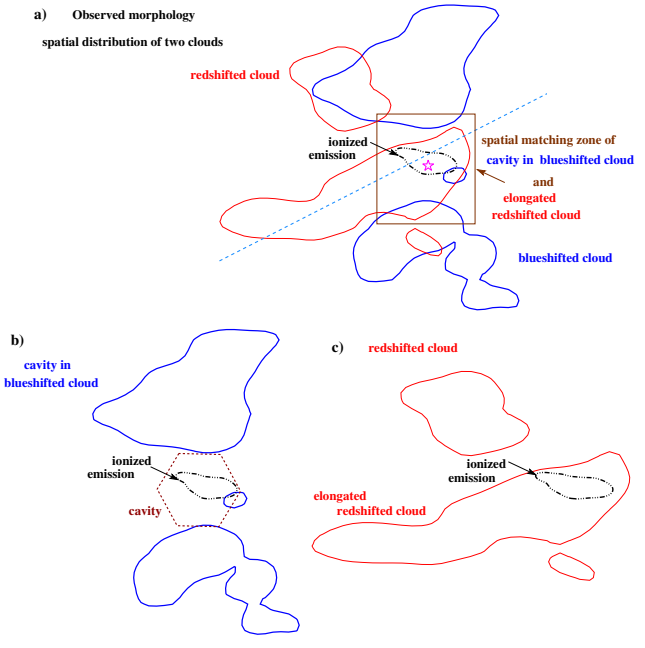


Figure no. 10. a) Spatial distribution of two clouds (around 11.5 and 18.5 km $s^{-1}$) toward G8.14+0.23. A broken black contour represents the location of the G8.14+0.23 H ii region. b) A cavity (or intensity-depression) in the cloud around 11.5 km $s^{-1}$. c) The H ii region in the cloud around 18.5 km $s^{-1}$.

**(L. K. Dewangan)**

### Observational signatures of end-dominated collapse in the S242 filamentary structure

The space-based infrared and sub-millimeter (sub-mm) data have unveiled numerous filamentary features, where mid-infrared bubbles/shells associated with H II regions, embedded clumps, and clusters of young stellar objects are commonly identified. The physical

mechanisms of filament fragmentation and the role of filaments in the formation of dense massive star-forming clumps and young stellar clusters are still debated. In this context, we have analyzed new CO ($^{13}$CO(1–0) and C$^{18}$O(1–0)) and CS(2–1) line observations of an elongated filamentary structure (length ∼30 pc) in the star-forming site S242, which were taken with the OSO-20m telescope. The S242 H II region is found to be powered by a massive B0.5V–B0V star. One filament's end hosts the S242 H II region, while the other end contains Planck cold clumps. Several sub-regions are identified in the filament (see Figure no.11), and are supersonic with Mach number of 2.7–4.0. The study of the dynamical states shows supercritical nature of the sub-regions (except central part; see Figure no.11), which could not be supported by a combination of thermal and turbulent motions.

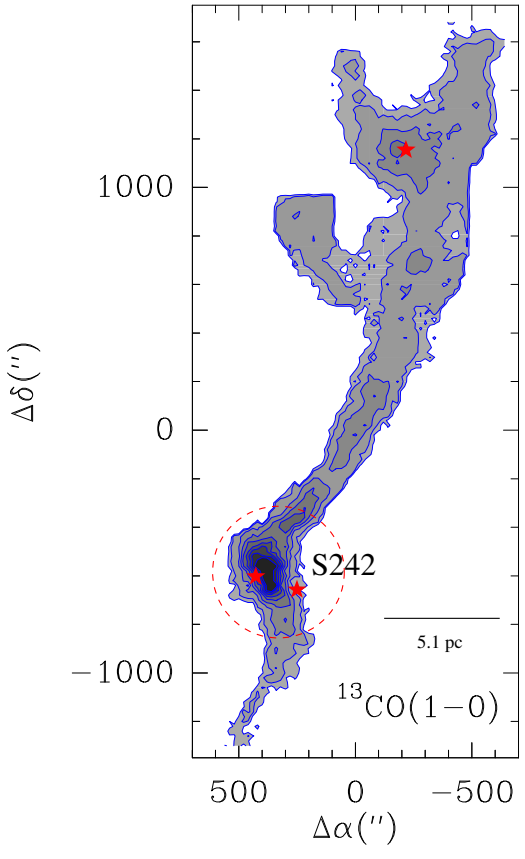


Figure no. 11: Contour map of the $^{13}$CO(1–0) integrated intensity emission at [-12, 6] km s$^{-1}$ toward the site S242. The axes are offsets with respect to a central position (i.e., RA (2000) = 5h 52m 12.9s; Dec (2000) = 26° 59′ 33″).

Young stellar objects are seen toward the entire filament, but more concentrated toward its ends. Dense molecular cores are observed mainly toward the filament ends, and are close to virial equilibrium. Position-velocity plots trace velocity gradients (∼1 km s$^{-1}$ pc$^{-1}$) toward both the ends. An oscillatory pattern in velocity is also observed toward the filament, indicating its fragmentation. The collapse timescale of the filament is computed to be ∼3.5 Myr. Using the $^{13}$CO data, the structure function in velocity of the filament is found to be very similar as seen in the Musca cloud for lags ∼1–3 pc, and deviates from the Larson's velocity-size relationship. The observed oscillatory pattern in the structure function at higher lags suggests the existence of large-scale and ordered velocity gradients as well as the fragmentation process through accretion along the filament. Considering all the observed results along with their uncertainties, the S242 filament is a very good example of the end-dominated collapse.

This work was done in collaboration with L. E. Pirogov (IAPRAS, Russia), O. L. Ryabukhina (IAPRAS, Russia), D. K. Ojha (TIFR, India), and I. Zinchenko (IAPRAS, Russia).

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**(L. K. Dewangan)**

**Cluster-forming site AFGL 5157: colliding filamentary clouds and star formation**

In the hydrodynamical simulations of the collision process, massive clumps and cores are produced at the junction of two filamentary molecular clouds or the shock-compressed interface layer, where massive OB stars (≥ 8 M$_\odot$) can be formed. However, the observational confirmation of such physical process or a colliding event is a very difficult task. In this context, we have observationally investigated star formation process occurring in AFGL 5157 (area ∼13.5 pc × 13.5 pc) using a multi-wavelength approach.

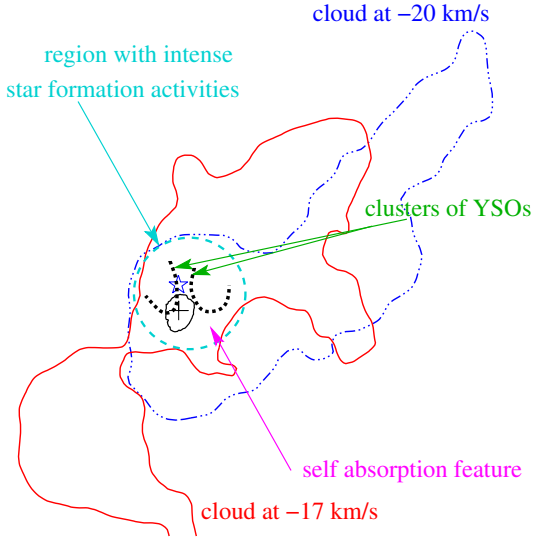


Figure no. 12. Spatial distribution of two clouds (around -20 and -17 km s$^{-1}$) at large-scale environment of AFGL 5157. A broken circle indicates the area associated with star formation. Two arc-like curves highlight clusters of young stellar objects.

Embedded filaments are seen in the Herschel column density map, and one of them is identified as an elongated filamentary feature (length ∼8.3 pc; mass ∼1170 M$_\odot$). Five Herschel clumps (M$_{clump}$ ∼45–300 M$_\odot$) are traced in the central part of filamentary feature, where an extended temperature structure (T$_d$ ∼13.5–26.5 K) is observed. In the direction of the central part of filamentary feature, the warmer region at T$_d$ ∼20–26.5 K spatially coincides with a mid-infrared shell surrounding a previously known evolved infrared cluster. Diffuse H$\alpha$ emission is traced inside the infrared shell, suggesting the presence of massive stars in the evolved cluster. Based on the surface density analysis of young stellar objects,

embedded clusters of young stellar objects are traced toward the central part of filamentary feature, and are distributed around the infrared shell. Previously detected $H_2O$ masers, $H_2$ knots, massive protostar candidates, and H II region are also seen toward the embedded clusters. In the large-scale area around AFGL 5157, a schematic figure is shown in Figure no. 12, which displays the spatial distribution of two clouds (around -20 and -17 km $s^{-1}$) and the area associated with the intense star formation activities (see a broken circle in Figure no. 12). We have also highlighted the locations of the embedded clusters by two arc-like curves in the figure. The central part of filamentary feature is observed at the overlapping zones of these two filamentary molecular clouds (length $\sim$12.5 pc), which are also connected in velocity. Our observational results suggest that the formation of massive stars appears to be triggered by a collision of two filamentary molecular clouds, which might have also influenced the birth of young stellar objects in AFGL 5157.

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**(L. K. Dewangan)**

### Unveiling Properties of Dark Globule LDN 1225: Distance, Extinction Law, and Magnetic Fields

We present the results based on the optical R-band polarization observations of 280 stars distributed towards the dark globule LDN 1225. Gaia data release 2 parallaxes along with the polarization data of $\sim$ 200 stars have been used to (a) constrain the distance of LDN 1225 as 830$\pm$83 pc, (b) determine the contribution of interstellar polarization (ISP), and (c) characterize the dust properties and delineate the magnetic field (B-field) morphology of LDN 1225. We find that B-fields are more organized and exhibit a small dispersion of 12°. Using the $^{12}$CO molecular line data from the Purple Mountain Observatory (PMO), along with the column density, dispersion in B-fields, we estimate B-field strength to be $\sim 56 \pm 10\,\mu$G, magnetic to turbulence pressure to be $\sim 3 \pm 2$, and the mass-to-magnetic flux ratio (in units of critical value) to be $< 1$. These results indicate the dominant role of B-fields in comparison to turbulence and gravity in rendering the cloud support. B-fields are aligned parallel to the low-density parts (traced by $^{12}$CO map) of the cloud, in contrast they are neither parallel nor perpendicular to the high-density core structures (traced by $^{13}$CO and C$^{18}$O maps). LDN 1225 hosts two 70 $\mu$m sources which seem to be of low-mass Class 0 sources. The total-to-selective extinction derived using optical and near-infrared photometric data is found to be anomalous ($R_V = 3.4$), suggesting dust grain growth in LDN 1225. Polarization efficiency of dust grains follows a power-law index of -0.7 inferring that optical polarimetry traces B-fields in the outer parts of the cloud.

This work has been done in collaboration with C. Eswaraiah, S.-P. Lai (NTHU, Taiwan), Y. Ma (PMO, China), A. K. Pandey (ARIES, Nainital), J. Jose (IISER, Tirupati) ,and other team members from various national and international institutes/organizations.

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**(M. R. Samal)**

### Understanding the Origin of [C II] 158 m Emission toward the H II Region Complexes with SOFIA: A Case Study on S235

Although the $^2P_{3/2} - ^2P_{1/2}$ transition of [C II] at $\lambda \simeq 158\,\mu$m is known to be an excellent tracer of active star formation, we still do not have a complete understanding of where within star formation regions the emission originates. Here, we use *SOFIA* upGREAT observations of [C II] emission (shown in Figure no. 13a) toward the HII region complex Sh2-235 (S235) to better understand in detail the origin of [C II] emission. We complement these data with a fully-sampled Green Bank Telescope radio recombination line map tracing the ionized hydrogen gas. About half of the total [C II] emission associated with S235 is spatially coincident with ionized hydrogen gas, although spectroscopic analysis shows little evidence that this emission is coming from the ionized hydrogen volume (shown in Figure no. 13b).

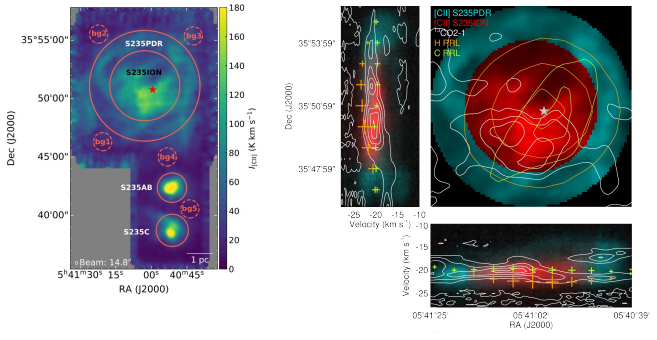


Figure no. 13: a) Integrated (-29 to - 12 km/s) intensity map of SOFIA [C II] 158data, smoothed by a 33 pixel Gaussian kernel (approximately the beam size). The red circles enclose regions of interest, with dashed circles denoting background regions. The filled red star marks the position of the ionizing source BD+351201. The smaller HII regions show strong and compact [C II] emission. b) Position-velocity analysis of [C II] emission toward S235MAIN. The top right panel shows the moment 0 integrated intensity map of [C II] emission, color coded with S235ION in red and S235PDR in cyan. White contours are of 13 CO 2 - 1 moment 0 emission and green contours are of RRL moment 0 emission. The gray star symbol shows the location of the ionizing source. The other two panels show p-v diagrams with the same color scheme and 13 CO 2 - 1 contours. The green crosses show the velocity derived from Gaussian fits to RRL data integrated along a spatial direction; the size of the crosses indicate the amplitude. [C II] emission seen in the direction of S235ION is blue shifted relative to the ionized hydrogen gas, whereas that of S235PDR is found at a broader range of velocities. We find no evidence of significant [C II] emission from the ionized hydrogen volume.

Velocity-integrated [C II] intensity is strongly correlated with *WISE* 12 $\mu$m intensity across the entire complex, indicating that both trace ultra-violet radiation fields. The 22 $\mu$m and radio continuum intensities are only correlated with [C II] intensity in the ionized hydrogen portion of the S235 region and the correlations between the [C II] and molecular gas tracers are poor across the region.

We find similar results for emission averaged over a sample of external galaxies, although the strength of the correlations is weaker. Therefore, although many tracers are correlated with the strength of [C II] emission, only WISE 12 $\mu$m emission is correlated on small-scales of the individual [C II] region S235 and also has a decent correlation at the scale of entire galaxies. Future studies of a larger sample of Galactic [C II] regions would help to determine whether these results are truly representative.

This work has been done in collaboration with L. Anderson, Z. Makai, L. Luisi (West Virginia University, USA), M. Andersen (Gemini South, Chile), D. Russeil (LAM, France) and other team members from various international institutes/organizations.

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**(M. R. Samal)**

**First Results from MFOSC-P : Low Resolution Optical Spectroscopy of a Sample of M dwarfs within 100 parsecs**

In recent times, M dwarfs show great interest for exoplanets searches since they are found to host exoplanets in habitable zone. Determination of their accurate atmospheric properties and fundamental parameters is essential to constrain both their atmospheric and evolutionary models.

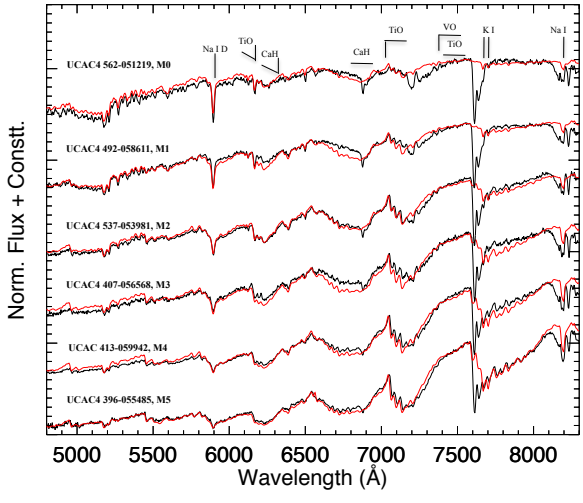


Figure no. 14 : SDSS template spectra (red) is compared with observed spectral sequence of M dwarfs (black). Representative spectra of different subclasses from our sample are chosen to show the match. The most prominent spectral features along with the derived spectral type are also labeled.

In this study, our aim is to provide a low resolution spectroscopic catalogue of 80 bright M dwarfs (R $\sim$ 500) in the visible waveband. Further, we aim to classify a sample of M dwarfs using their optical spectra. We have also performed the spectral synthesis and $\chi^2$ minimisation techniques to determine their fundamental parameters viz. effective temperature and surface gravity by comparing the observed spectra with the most recent BT-Settl synthetic spectra. Spectral type of M dwarfs in our sample ranges from M0 to M5. The derived effective temperature and surface gravity are ranging from 4000 K to 3000 K and 4.5 to 5.5 dex, respectively. In most of the cases, the derived spectral types are in good agreement with previously assigned photometric classification. This is the first science result obtained with the newly commissioned MFOSC-P instrument on the PRL 1.2m telescope.

This work has been done in collaboration with Prof. France Allard of Univ Lyon, Ens de Lyon, France and Dr. D. Homeier of Zentrum fr Astronomie der Universitt Heidelberg, Landessternwarte, Knigstuhl 12, 69117 Heidelberg, Germany.

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**(A. S. Rajpurohit, M. K. Srivastava, V. Kumar, V. Dixit and A. Patel)**

**Discovery of a rare pre-main-sequence Herbig Ae/Be star VES 263**

Massive Pre-main-sequence stars are very rare, only about a dozen such objects have been identified till date. We have discovered a bonafide massive pre-Main Sequence object: VES 263 using our long term, high cadence, optical and near-infrared photometric and spectroscopic observations.

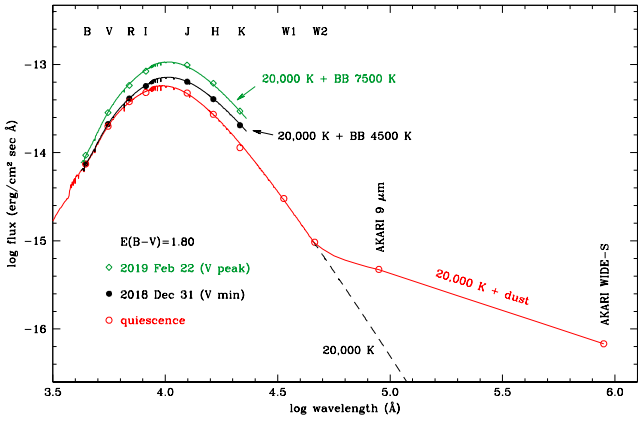


Figure no. 15: The spectral energy distribution of VES 263 at three distinct states (quiescence, minimum and peak brightness during the current eruption). The SED in quiescence is fitted with a synthetic spectrum for the B1II star and black-body emission over 400-25 K for the dust. Black-bodies are added to the B1II star for the other epochs (all reddened by the same E(B-V) =1.80).

VES 263 is so far a neglected emission-line object discovered in the 1960s on objective prism plates, tentatively classified as a semi-regular AGB cool giant by automated analysis of ASASSN lightcurves. GAIA has recently identified a brightening episode in 2018. We have also reconstructed from Harvard, Moscow and Sonneberg photographic plates the photometric history of VES 263 from 1896 to 1995. Our analysis inferred that the star is of the Herbig AeBe type with mass of about 12 M$\odot$. It is located at 1.68$\pm$0.07 kpc distance, within the Cyg OB2 star-forming region, and it is highly reddened (E(B-V) =1.80$\pm$0.05) by interstellar extinction. In quiescence, the spectral energy distribution is dominated by the $\sim$20,000 K photospheric emission from the central B1II star, and at $\lambda > 6\mu$m by emission from circumstellar warm dust (T $<$ 400K). The 2018-19 eruption was caused by a marked brightening of the accretion disk around the B1II star as traced by the evolution with time of the integrated flux and the double-peaked profile of emission lines. At the peak of the eruption, the disk has a bulk temperature of $\sim$7500 K and a luminosity L $>$ 860 L$\odot$, corresponding to a mass accretion rate $>$ 1.1$\times10^{-1}$ M$\odot$ yr$^{-1}$. Spectroscopic signatures of possible bipolar jets (at -700 and +700 km s$^{-1}$ ) of variable intensity are found.

black-body emission over 400-25 K for the dust. Blackbodies are added to the B1II star for the other epochs (all reddened by the same E(B-V) =1.80).

This work has been done in collaboration with Prof. Ulisse Munari of INAF Astronomical Observatory of Padova, Italy, Prof. K. Koter, Faculty of Mathematics and Physics, University of Ljubljana, Slovenia and Dr. Shugarov S.Y., Sternberg Astronomical Institute, M.V. Lomonosov Moscow State University, Russia.

doi : https://doi.org/10.1093/mnras/stz2078

**(V. Joshi and D. P. K. Banerjee)**

### An Evolving Broad Iron Line from the First Galactic Ultraluminous X-Ray Pulsar Swift J0243.6+6124

The X-ray transient Swift J0243.6+6124 was discovered with the Neil Gehrels Swift Observatory in 2017 October during the onset of a strong. Detection of 9.8s pulsations identified the source as an X-ray pulsar. Swift J0243.6+6124 harbors a highly magnetized neutron star ($\leq 10^{13}$ G), accreting from a massive optical companion of Oe- or early Be-type. The constraint on its magnetic field is obtained tentatively using the independent methods based on the "propeller" luminosity from the source flux evolution, measuring the critical luminosity from hardness ratios, and also from the detected quasi-periodic oscillations in NICER data. The system has a 27.6 days eccentric orbit and is located at a distance of $\sim$ 7 kpc. The 2017 giant outburst from the system lasted approximately five months, with a peak X-ray luminosity $\sim 10^{39}$ erg s$^{-1}$, which exceeds the Eddington limit of a neutron star. This luminosity classified the source as an ultraluminous X-ray (ULX) pulsar, the very first detected inside our Galaxy. ULXs are powerful, off-nuclear (extragalactic), point-like sources, emitting at a luminosity $\geq 10^{39}$ erg s$^{-1}$. A few of them are pulsars with spin periods in the range 130 s. It remains unclear what powers these sources. A possible explanation comes from a combination of super-Eddington accretion and geometric collimation effect.

Using Neutron Star Interior Composition Explore (NICER) observations, we explored the spectral characteristics of the ultraluminous pulsar Swift J0243.6+6124 during the 20172018 strong outburst. The 1.210 keV energy spectrum of the source, obtained from NICER observations, can be approximated with an absorbed cutoff power-law model. We detect strong, luminosity-dependent emission lines in the 67 keV energy range (Figure no. 16). A narrow 6.42 keV line, observed in the sub-Eddington regime, is seen to evolve into a broad Fe-line profile in the super-Eddington regime. Other features are found at 6.67 and 6.97 keV in the Fe-line complex. An asymmetric broad-line profile, peaking at 6.67 keV, is possibly due to Doppler effects and gravitational redshift. The 1.279 keV broadband spectrum from Nuclear Spectroscopic Telescope Array (NuSTAR) and NICER observations at the outburst peak is well described by an absorbed cutoff power law plus multiple Gaussian lines and a blackbody component. Physical reflection models are also tested to probe the broad iron-line feature. Depending on the mass accretion rate, we found emission sites that are evolving from 5000 km to a range closer to the surface of the neutron star. Our findings are discussed in the framework of the accretion disk and its implication on the magnetic field, the presence of optically thick accretion curtain in the magnetosphere, jet emission, and the massive, ultrafast outflow expected at super-Eddington accretion rates. We do not detect any signatures of a cyclotron absorption line in the NICER or NuSTAR data.

This work was done in collaboration with Gaurava K. Jaisawal of National Space Institute, Technical University of Denmark, Denmark.

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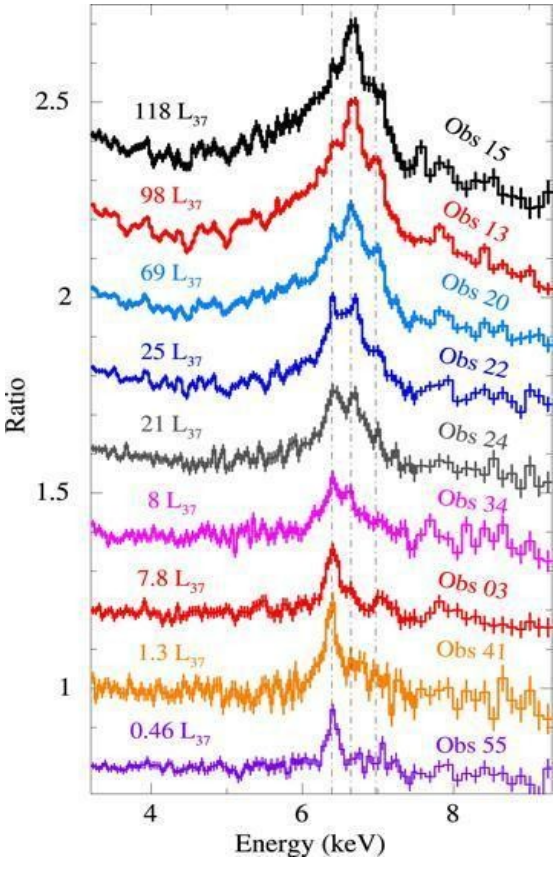


Figure no. 16:Ratio of NICER data to the continuum model obtained by fitting 1.2–10 keV energy spectra of Swift J0243.6+6124, arranged in order of increasing luminosity in the units of $L^{37}$ ($10^{37}$ erg s$^{-1}$) . Three emission lines in the 6–7 keV range are detected at 6.4, 6.67, and 6.98 keV energies (vertical dashed-dotted lines).

**(S. Naik)**

### NuSTAR view of Be/X-ray binary pulsar 2S 1417-624 during 2018 giant outburst

Be/X-ray binary pulsars, which form $\sim$67% of the known High Mass X-ray Binary (HMXB) systems, are generally transient X-ray sources in the sky. The neutron star and a Be companion star in the binary system rotate around the common center of mass in wide and eccentric orbits with orbital period in the range of tens of days to several hundred days. The observed transient activity in these sources are known to be due to the capture of huge amount of mass from the

equitorial circumstellar disk of the Be star at the periastron passage. Due to mass transfer from the circumstellar disk to the neutron star at periastron passage, the X-ray luminosity of the neutron star (pulsar) increases by a few orders of magnitude. This sudden increase in the the X-ray luminosity is called as X-ray outburst. The Be/X-ray binary pulsars are known to exhibit two types of X-ray outbursts, such as Type-I and Type-II X-ray outbursts. Type-I outbursts are periodic X-ray events that usually occur at the periastron passage of the neutron star in the Be/X-ray binary systems. These events last for about 20-30% duration of the binary orbit. However, there are X-ray outbursts observed from these Be/X-ray binary pulsars during which the peak luminosity exceeds by orders of magnitude higher compared to that during Type-I outbursts. These events are known as Type-II (giant) X-ray outbursts. These events are observed occasionally for a duration of a few weeks to a few months and are independent of the orbital phase of the binary. It has been observed that the properties of the neutron star in these systems show strong dependence on its X-ray luminosity. Therefore, it is interesting to understand the characteristic properties of these objects at broad luminosity ranges during X-ray outbursts. This will provide information on the geometry and evolution of the binary system.

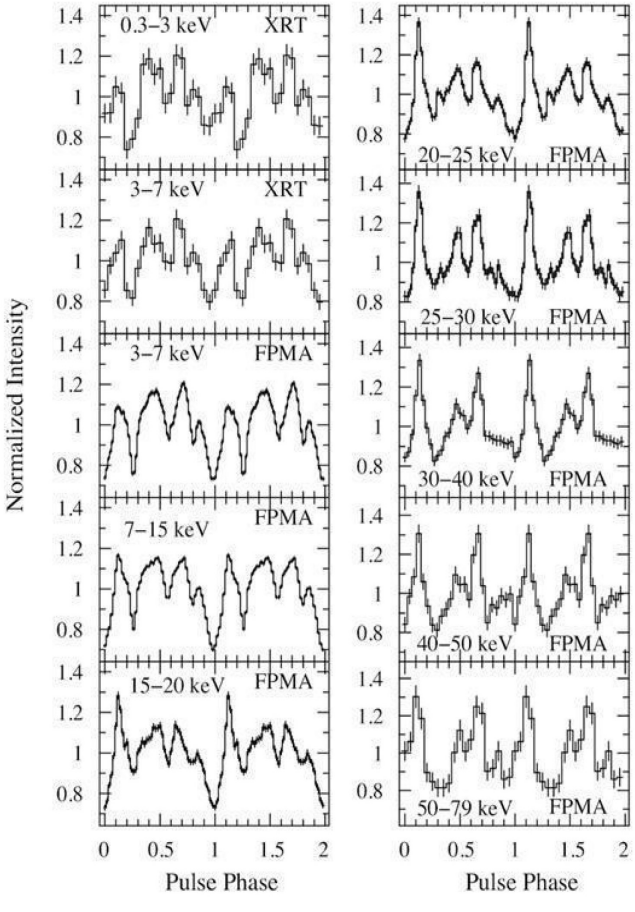


Figure no. 17 : Energy resolved pulse profiles of 2S 1417-624, obtained from Swift and NuSTAR observations during the 2018 May outburst. A strong energy dependence could be traced easily among successive profiles.

Several Type-I and Type-II X-ray outbursts have been observed in the Be/X-ray binary pulsar 2S 1417-624. Among those, the giant outburst observed in 2009 has been studied in detail by using the RXTE observations of the pulsar. The pulsar had gone into another giant X-ray outburst recently (in 2018) during which it was observed with Swift and NuSTAR observatories. We have carried out a detailed analysis of these data taken at the peak of the outburst. X-ray pulsations at 17.475 s were detected in the light curves up to 79 keV. The evolution of the pulse profiles of the pulsar with energy was found to be complex. A four-peaked profile at lower energies gradually evolved into a double-peak structure at higher energies (Figure no. 17). The pulsed fraction of the pulsar, calculated from the NuSTAR observation was found to follow an anticorrelation trend with luminosity as observed during previous giant X-ray outburst studies in 2009. The broad-band spectrum of the pulsar is well described by a composite model consisting of a cut-off power-law model modified with the interstellar absorption, a thermal blackbody component with a temperature of 1 keV, and a Gaussian function for the 6.4 keV iron emission line. Though the pulsar was observed at the peak of the giant outburst, there was no signature of presence of any cyclotron line feature in the spectrum. The radius of the blackbody emitting region was estimated to be $\sim$2 km, suggesting that the most probable site of its origin is the stellar surface of the neutron star. Physical models were also explored to understand the emission geometry of the pulsar.

This work was done in collaboration with G. K. Jaisawal of National Space Institute, Technical University of Denmark, Denmark.

doi : https://doi.org/10.1093/mnras/stz2795

**(S. Gupta and S. Naik)**

**A retrograde motion for the black-hole in the galactic X-ray binary MAXI J1659152**

An astrophysical black hole is characterised by two properties - mass and angular momentum. Unlike mass, accurate estimation of angular momentum, denoted by a dimensionless spin parameter (-1 $<$ a (= cJ/GM$^2$ ) $<$ 1), is difficult because of the unknown system parameters as well as due to unavailability of high resolution broadband data. The spin of stellar-mass black holes in X-ray binaries is reminiscent of the natal kick received during supernovae explosions and thus should be randomly distributed across the black-hole population. However, on observational grounds, most of the black holes are found to have positive spin with only one or two reports hinting the possibility of negative spin. With detailed X-ray spectroscopic analysis of the galactic black hole X-ray binary MAXI J1659152, we showed that the black hole in this binary system most likely have negative spin. We analyzed simultaneous the XMM-Newton/EPIC-pn and RXTE/PCA observations observations of this X-ray binary carried during its 2010 outburst. The 0.7-40.0 keV spectrum was fitted with a combination of multi-color blackbody and power law components.

The EPIC-pn spectrum showed the presence of a broad Fe-line centered around 7 keV which was verified using Monte-Carlo simulations. In order to account for the reflection features in the spectra the state-of-the-art reflection code relxill was added. The crucial part of this analysis was that that constraint on spin was obtained despite the unknown black-hole mass (M) and distance (D). For this purpose, a novel analysis method was adopted by fixing M and D to a range of values, reported by previous studies, and then fitting for mass accretion rate. All other parameters were left free to vary. An upper limit on the spin was arrived by considering various reasonable estimates on limit of the accretion rate based on previous studies. We

also applied two different methods to estimate spin the spin and both provided similar upper limits.

Thus, it is concluded that for a large parameter space ($\sim$ 95%) the spin of the black hole in MAXI J1659152 is negative or zero. This result opens up the possibility that retrograde motion in black holes is a norm rather than exception.

doi : https://doi.org/10.3847/2041-8213/ab629e

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

**Multiwavelength Studies of Active Galactic Nuclei**

Active galactic nuclei (AGNs) exhibit variable and complex spectral energy distribution. The central engine of an AGN, an accreting supermassive black hole (SMBH), is known to radiate in the luminosity range $10^{41-47}$ erg $s^{-1}$ almost equally over the entire electromagnetic spectrum. In the brightest AGN, the intense radiation emitted from the central engine dominates the light coming from other constituents of the host galaxy such as stars. The huge energy release in these objects is attributed to accretion onto the supermassive black hole. The X-ray continuum emission from these objects is considered to be dominated by the power law model, which is known to be due to the inverse Compton scattering of soft photons, emitted from the accretion disk around the SMBH, in an optically thin and hot electron plasma ($kT_e \sim 100$ keV). In Seyfert galaxies, radiation emitted from the accretion disc is dominated in the UV band. However, due to large Galactic absorption along the line of sight, the UV radiation peak is hardly detectable. The observed UV/optical emission shows different variabilities on various time-scales from days to years for $10^{6-9}$ $M_\odot$ black hole mass range. However, the cause of observed variabilities in UV/optical emission from the accretion disc is not very clear.

Large flux variations in X-ray and UV/optical ranges, on the timescales of hours to years, are very common in AGNs. There are different proposed physical mechanisms for these variabilities. Longer variations of the order of months to years may belong to the propagation of fluctuations in the accretion disk while short-term variations are associated with reprocessing of shorter wavelength radiation into longer wavelengths. We aim for a detailed variability study of Seyfert 1 galaxy Mrk 509 in UV/optical and X-ray bands to find the cause of variability and correlation between them to identify the dominant physical process going on in the system. This AGN is being monitored with the Swift satellite since 2006 at irregular intervals.

A large number of observations and simultaneous look of the source in UV/optical and X-ray, covering many epochs, gives us the opportunity for a detailed analysis in terms of long-term as well as short-term variabilities. We use about 297 exposures in six UV/optical and X-ray (0.3-10 keV) band in our study. The X-ray spectra in 0.3-10 keV range are well described by a model consisting of an absorbed power law and blackbody in the soft band (0.3-1.0 keV). Using correlation analysis, we test the existing assumptions in the standard Shakura-Sunyaev disk. The different time-lags found between X-ray and UV/optical energy bands give insight to the extent of accretion disk.

doi : https://doi.org/10.25518/0037-9565.8767

**(N. Kumari and S. Naik)**

**PKS 2250-351: A Giant Radio Galaxy in Abell 3936**

We present a detailed study of a giant radio galaxy PKS 2250-351 which shows projected linear size of 1.2 Mpc (see Figure no. 18). We model the jet power and estimate the age of radio lobes by using multi-frequency radio observations from the Murchison Wide-field Array, the upgraded Giant Metre-wavelength Radio Telescope, the Australian Square Kilometre Array Pathfinder, and the Australia Telescope Compact Array. We find that the lobe-derived jet power (a time-averaged measure) is an order of magnitude greater than the hotspot-derived jet power (an instantaneous measure). We propose that over the lifetime of the observed radio emission ($\sim$ 300 Myr) the accretion has switched from an inefficient advection dominated mode to a thin-disc efficient mode, consistent with the decrease in jet power. We also suggest that the asymmetric radio morphology is due to its environment, with the host of PKS2250-351 lying to the west of the densest concentration of galaxies in Abell 3936 . Optical and infra-red data obtained from the Galaxy And Mass Assembly (GAMA) confirms that PKS 2250-351 lies at z = 0.2115 in the irregular, and likely unrelaxed, cluster Abell 3936. We find its host is a massive, red and dead elliptical galaxy with negligible star formation but with a highly obscured active galactic nucleus dominating the mid-infrared emission.

This work has been done in collaboration with Dr. N. Seymour (Curtin University, Australia), Dr. M. Huynh (CSIRO Astronomy and Space Science Australia) and other collaborators within the Evolutionary Map of Universe (EMU) program.

doi : https://doi.org/10.1017/pasa.2019.49

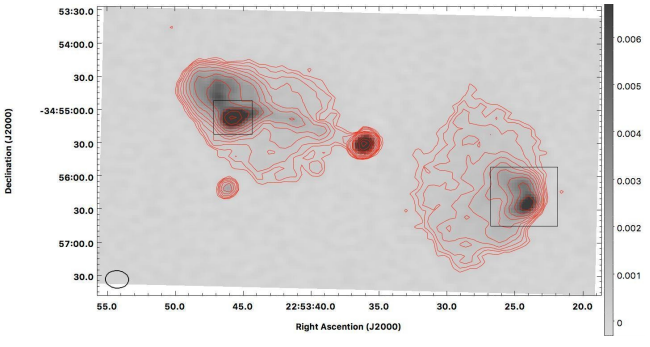


Figure no. 18: Greyscale image of PKS 2250-351 from 888 MHz ASKAP continuum data. The red contours start at $4\sigma$ and increase by factors of $\sqrt{2}$. The core is clearly identified as well as hotspots positioned on top of diffuse emission from the lobes. Within the eastern lobe the jet is observed with several knots.

**(V. Singh)**

**On-sky commissioning of MFOSC-P on PRL 1.2m Telescope**

Mt. Abu Faint object spectrograph and camera Pathfinder (MFOSC-P) instrument was commissioned on PRL 1.2m Telescope at Mt.Abu in February 2019. Subsequently a series of commissioning tests and

science observations were carried out to ensure and confirm the on-sky performance of the instrument in its spectroscopy and imaging modes. Telescope optics and seeing at the site dominates the imaging PSF of MFOSC-P. M21 open cluster was observed with MFOSC-P to characterize its imaging performance. Figure no. 19 shows the image of a portion of M21 open cluster observed with the V filter of MFOSC-P. Photometry of one of the faint sources (encircled in Figure no. 19) with magnitude 15.74 gives the photometric error of 0.15 mag corresponding to SNR of 7.3, in 40 sec of integration time.

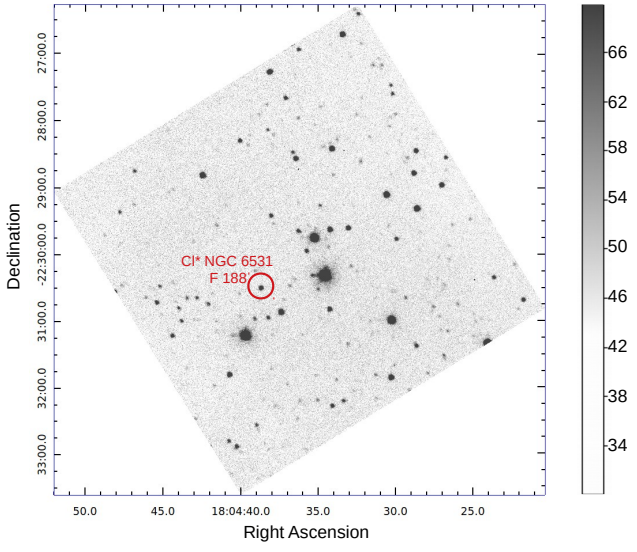


Figure no. 19: Images of M21 Open Cluster obtained by MFOSC-P in V filter. A 15.74 V magnitude source (encircled) is observed with error of 0.15 magnitude (SNR $\sim$ 7.3) in 40 sec of integration time.

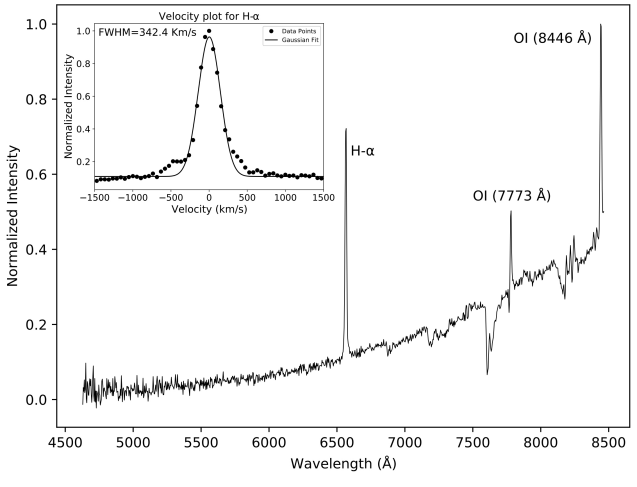


Figure no. 20: Low resolution spectra of Nova AT2019QWF with integration time of 300 seconds as observed with MFOSC-P.

MFOSC-P carries three gratings for different resolutions and spectral ranges, viz. (a.) grating-1 : dispersion of $\sim$3.8 Å per pixel and spectral range of 4500 - 8500 Å (b.) grating-2 : dispersion of $\sim$1.9 Å per pixel and spectral range 4600 - 600 Å and (c.) grating-3 : dispersion of $\sim$1.1 Å per pixel and spectral range 6000-7000 Å. These resolutions modes have been verified using suitable targets over the last one year since commissioning of the instrument. Figure-20 shows the spectra of nova AT2019qwf as recorded with MFOSC-P on UT 2019-11 - 01.71 with 300sec of integration time. It is to be noted that nova was of V magnitude $\sim$16 on the day of observations. The low-resolution spectra showed a highly-reddened continuum with prominent H$\alpha$ emission and OI lines at 7773 Å and 8446 Å. The above has been reported to Astronomical Telegrams (Srivastava et al. 2019, Astronomical Telegrams No. 13258).

**(M. K. Srivastava, V. Kumar, V. Dixit, A. Patel and A. S. Rajpurohit)**

### The upcoming PRL 2.5m telescope at Gurushikar, Mt. Abu

PRL is going to acquire a new 2.5m telescope some time in 2021 which is currently being developed at AMOS facility in Belgium. The design of this is based upon the science need and various back-end instruments that are being designed and developed at PRL.

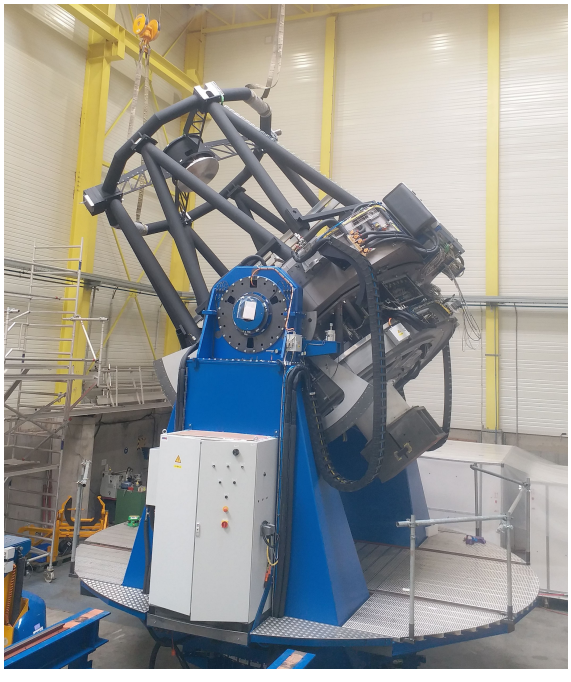

Figure no. 21: State-of-the-art PRL 2.5m telescope being developed and tested for performance at AMOS facility in Belgium.

This telescope will be fully auto-remote mode and with state-of-the-art Active Optics system for precision image quality. The telescope will also have a first order AO correction tip-tilt system working up to 20Hz. This is for the first time such a seeing correction system will be available in the country along with the telescope. Figure no. 21 below shows the 2.5m telescope being tested at AMOS facility in Belgium. There will be two first light instruments which will see first light along with the telescope around mid-2021: a) PARAS-2, which will be an unique temperature stabilized at 0.001 $^{\circ}$C at 20 $^{\circ}$C and vacuum stabilized at 0.001mbar high resolution spectrograph at resolution of 100,000. It is being designed and developed at PRL to achieve less than 1m/s radial velocity precision for the detection of

super Earths around the Sun like stars and stellar astrophysics. The spectrograph design and the vacuum chamber design is complete and is expected to be ready by December 2020. We have recently finished the installation of the 6144 x 6200 pixels very large CCD array detector; the largest physical array size possible 92mm x 92mm (in physical size). This is also for the first time that such a large array detector working in the wavelength region of 380nm to 800nm is being installed in the country and optimized its operation. Figure no. 22 shows installation of the detector in the Cryogenic system in the PRL lab facility. After optimization, the detector showed read noise of 4.5 electrons and gain of 2, with dark noise of 0.1electrons per pixel per sec at -113 $^{\circ}$C. b) CCD imager with high throughput SDSS filters in the wavelength region of 350nm to 1000nm: This camera will be used for faint object photometry and precision differential photometry. Various astrophysical phenomena will be observed with this camera like: Novae, Supernova, GRBs, exoplanet transit photometry etc.

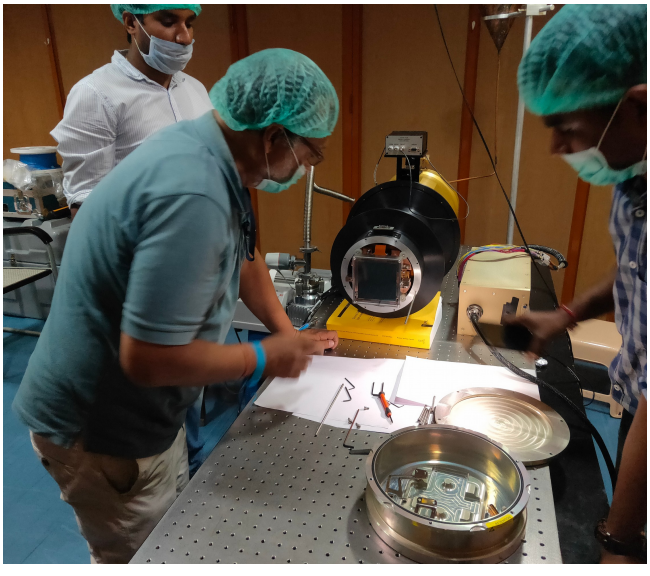

Figure no. 22: 6kx6k very large array CCD detector being installed inside PARAS-2 cryogenics system, this is the first time such a system is being installed in the country.

**(A. Chakraborty, N. J. S. S. V. Prasad, K. Kumar, K. Lad, A. Naik, R. Sharma and S. N. Mathur)**

**Adaptive Optics Test Bench Development**

**(i) Mathematical Modeling of Test-bench Setup:** A mathematical model is being developed for the experimental verification of adaptive optics laboratory test-bench. A novel generalized method has been devised to propagate a given wavefront using Angular Spectrum Propagation method. The model can take ZEMAX (an industry standard optical design software) design as input and simulate the wavefront phase variation as it propagates through various sub-systems. The model considers the physical effects like refractive index change with temperature/pressure and the computational issues like, scaling, sampling, aliasing etc. in an optimum way. The performance of various optical chains in the design have been simulated to recover or deduce the parameters like pupil position, magnification etc. An additional functionality has been introduced to propagate off-axis beams. This would be particularly useful in AO applications where wavefront sensing is done for one source in order to correct wavefront of nearby source. The whole AO simulation package consists of several individual subsystem modules.These modules work in object oriented programming mode where additional functionalities can be easily introduced. A Python queue approach has been adopted to run the whole simulation package in a synchronized fashion. Figure no. 23 shows simulated image frames generated by the Shack-Hartmann wavefront sensor(SHWFS) module of the package. The algorithm is designed to make use of a parallel programming approach and can be deployed in multi-core machines to carry out faster computations. Our model would find its application in not only AO simulations but also other variety of applications like Coronography etc. The work is currently under progress.

**(ii) Hot-air Based Turbulence Chamber :** An optical turbulence generator(OTG) is a device that provides a turbulent beam which mimics optical turbulence properties of Earths atmosphere. The main application of an OTG is characterization of Adaptive Optics(AO) test-bench. Numerous methods have been evolved and successfully applied for emulating optical turbulence. We decided to build a hot air based OTG which is based on mixing of ambient air and temperature controlled hot air at regulated air flows within a restricted chamber. A hot air based OTG has the advantage of adjusting turbulence strength over static phase screens. Our hot air based OTG has been fabricated in-house at PRL workshop. The OTG has been designed to incorporate following design considerations:-

- Temperature should have a uniform gradient within the flow
- The flow should be laminar
- The rejected air must be dragged away from the optical bench in order to avoid undesirable turbulence in the rest of the optical path.

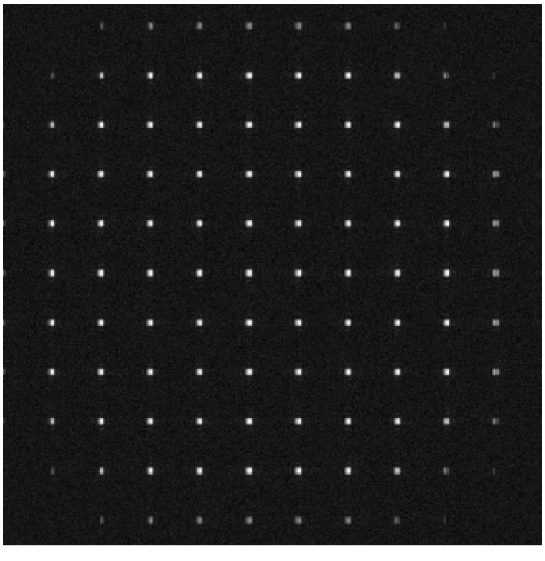

Figure no. 23: Image generated by Shack-Hartmann Wavefront Sensor simulator. Each spot corresponds to the image formed by a sub-aperture.

Two DC fans have been used to generate air flow and the flow rate is being adjusted by using pulse width modulation. A finned heater has been used so that there can be efficient transfer of heat from the heating coil to the air. With the help of temperature and velocity

sensors, provision has been made to achieve the desired temperature gradient and flow rate. Figure no. 24 shows an actual image of the turbulence chamber. The characterization process of the OTG is about to start.


Figure no. 24: Left: Various sensors and components of the hot air based optical turbulence generator(OTG). Right: Assembled OTG sensors being characterized in the electronics laboratory.

**(V. Dixit, A. Patel and M. K. Srivastava)**

**MFOSC-EP for PRL 2.5m Telescope: Optical Design of the Low Resolution Arm**

Mt. Abu Faint Object Spectrograph and camera Echelle Polarimeter is a proposed instrument for the upcoming 2.5m PRL Telescope at Mt. Abu. MFOSC-EP is an extended version of the FOSC series of instruments. The instrument is being designed for visible wavelengths as a general users observatory instrument. MFOSC-EP would be having the imaging as well as low resolution (resolution $<$ 2000) capabilities of a normal FOSC instrument in addition to the functionalities of an intermediate resolution spectro-polarimeter (resolutions 12000 and with polarimetry accuracy of $\sim$ 0.2%). The instrument layout is shown in Figure no. 25.

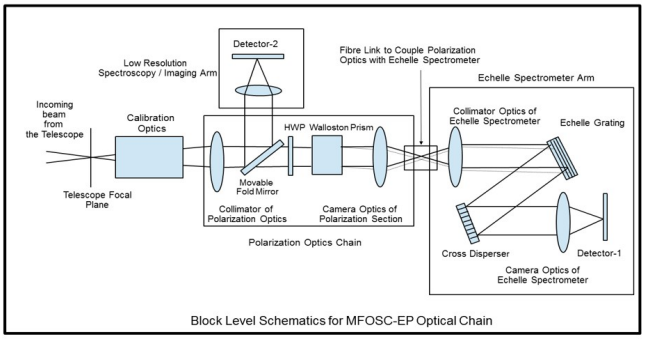


Figure no. 25 : MFOSC-EP Block Level System Schematic Diagram.

It is being designed with a modular optical system where a common collimator optics is coupled with two separate optical arms having two separate detector systems (i) for low resolution spectroscopy and band limited imaging and (ii) for intermediate resolution spectro-polarimetric mode. The low-resolution mode would use few grisms to provide low/medium resolutions spectroscopy (R $\sim$ 500–2000) and SDSS standard optical filters in camera optics-LR path for visible band imaging. In the Echelle-Polarimeter arm, f/8 beam from the telescope shall first be processed within a polarimetric unit based on half wave plate - Wollaston Prism combination. The collimator optics in this unit would make a pupil at the location of Wollaston prism. Coupled with camera optics, input beam from a point source would decompose in two orthogonal polarized components in the form of ordinary and extraordinary beams. These two beams shall be fed into the Echelle spectrometer for their simultaneous spectroscopy. The optical design of the Low-Resolution arm of MFOSC-EP has been successfully completed. The f/8 beam from the telescope is mapped onto 1K X 1K detector (with 13 $\mu$m pixel size) through collimator optics (designed with four optical elements: 2 singlet and 2 achromatic doublet lenses) and a camera optics (designed with 3 singlet and 2 achromatic doublet lenses). The camera optics provides f/3.2 beam onto the detector system to give de-magnification of X0.4. Three Grisms and SDSS standard filters are kept in the parallel beam space. EMCCD based camera system is being considered as a choice of the detector to enable the fast photometry applications in time domain science. The optical design of the polarization and echelle spectrometer part is currently in progress.

**(V. Kumar, V. Dixit and M. K. Srivastava)**

**Updates on the development of the NISP instrument for the 2.5 m telescope**

A Near Infrared Imaging Spectrometer and Polarimeter (NISP) is being developed at PRL as a multifaceted instrument for the 2.5 m telescope. It will provide imaging, spectroscopy & polarimetry modes in the Y, J, H, Ks filter pass bands i.e. over the 0.8 - 2.5 $\mu$m wavelength range. Optical, mechanical and electronics subsystems are designed and being developed in-house. The layout (Figure no. 26) showcases the lens assembly for the collimator & camera sub-systems. Optical design of NISP: The optical design of NISP is done using the OpticStudio - Zemax software. Collimator optics, from the telescope plane to the pupil of the instrument, is designed to transfer the image of the primary mirror onto the pupil stop. The spot sizes (RMS spot radius) of 8.7 $\mu$m, 7.2 $\mu$m, 11.2 $\mu$m, 7.6 $\mu$m at different field angles, achieved in our design, are well within the 0.3$''$ subtended by a pixel, indicating a very good design.

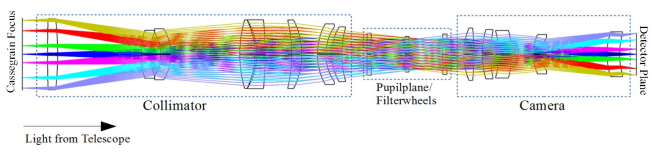


Figure no. 26: Optical Layout of NISP.

**Mechanical Aspects**: The mechanical layout for NISP consists of sub assemblies like H2RG detector assembly, cold-plate, collimator and camera assembly, filter wheel assembly, LN2 tank and a vacuum Dewar enclosing all these assemblies. All the sub assemblies are expected to operate in a stable manner under very extreme conditions of high vacuum and cryogenic temperature. To test these subsystems, a smaller version of the vacuum Dewar and LN2 tank were designed and built (see Figure no. 27).

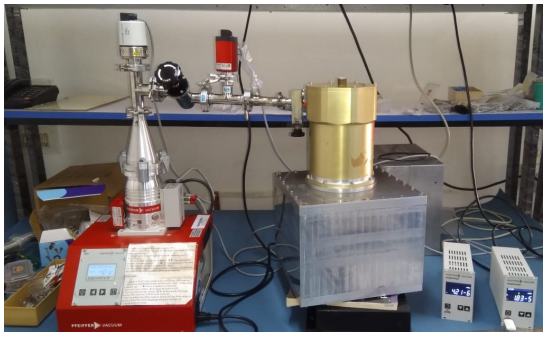

Figure no. 27: NISP Test Dewar Assembly.

The test Dewar encloses a liquid nitrogen tank connected to a cold plate. Dewar is equipped with feed-throughs for connecting gauge, vacuum pump and electrical connections. This chamber is designed to accommodate detector and filter wheel assembly. Entire detector assembly was tested and temperature distribution at various locations of the assembly were measured (see Figure no. 28) using 3 silicon diodes. The temperature profiles while cooling down are shown in the figure. A temperature of -193.85$^o$ Celsius (= 79.3 Kelvin) was achieved at the location of the detector (T1), with the maximum cooling rate of 4$^o$ C/min. The temperature profile at the detector support plate is shown in the curve labeled T2 while the temperature profile of the cold shield is shown in T3.

**Electronics Aspects**: NISP will employ a Teledyne science grade HAWAII-2RG (H2RG), 20482048 pixel array as the detector sensitive in the 0.8–2.5 $\mu$m wavelength range.

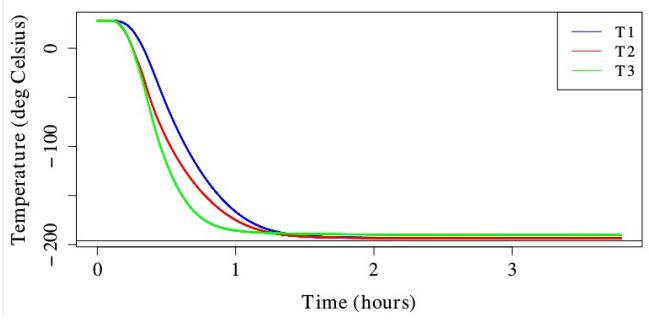


Figure no. 28: Evolution of temperature with time after pouring of LN2. Details of T1, T2, T3 are given in the text.

A single detector will be used for imaging, spectroscopy and polarimetry. However, the science grade detector is too expensive and sensitive to be used for development of electronics and software. Hence, we use a chip known as the Read Out Integrated Circuit (ROIC) for the developmental purpose. The ROIC is a silicon multiplexer of H2RG detector having identical electrical and mechanical interface of H2RG but without the light sensitivity. ROIC can work both at room and cryogenic temperatures which makes it very convenient during electronics and mechanical developments. The ROIC is connected to a host computer through an interface chip known as System for Image Digitization, Enhancement, Control and Retrieval (SIDECAR), via a Sidecar Acquisition Module (SAM) card setup in a 10,000 class clean room for NISP.

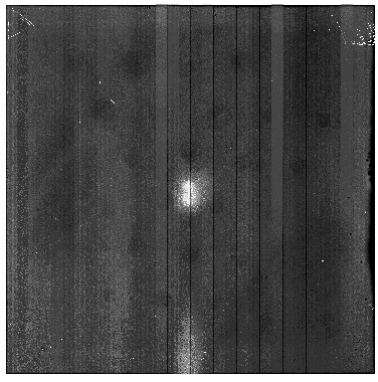

Figure no. 29 : Sample image taken using RT Setup. Optical beam is focused on the ROC.

Test images are obtained using the setup and a typical sample is shown in Figure no. 29. Indigenous electronics development, to interface with the SIDECAR, are also in progress. ROIC will be used to test and debug the indigenous electronics.

**(The NISP team: Alka, A. B. Shah, A. Rai, D. Sarkar, H. Adalja, K. S. Baliyan, P. S. Patwal, P. Prajapati, P. Kasarla, S. Naik, S. N. Mathur and S. Ganesh)**

**Development of hard X-ray mirrors foils for hard X-ray telescope**

A new activity for developing hard X-ray optics for future Indian X-ray astronomical mission as a potential successor of the Astrosat has been initiated in the Astronomy & Astrophysics division. At X-ray wavelengths, the refractive indices of all materials are close to unity, restricting the reflectivities to a very small grazing incidence angle (total external reflection). Hence, it is a common practice to employ small grazing incident angles to design X-ray reflecting optics. The critical angle for total X-ray reflection is inversely proportional to the energy of the incident X-rays and at energies higher than 10 KeV, the critical angle becomes too small to design an efficient optical system. To achieve reasonable X-ray reflectivity at higher energies it is essential to use multilayer mirrors consisting of a large number of alternate thin film layers, with thickness of the order of few nanometers, of high-Z and low-Z materials deposited on a highly polished substrate. If the thickness of the alternative bilayers is constant, the enhancement in reflectivity is usually limited to a narrow energy band satisfying the Bragg condition. However, by varying the thickness of the alternate high-Z and low-Z material in a controlled manner, it is possible to achieve broadband reflectivity for relatively larger incidence angles. With the advancement in the thin film fabrication technology, a variety of multilayer mirrors can be fabricated to reflect hard X-rays up to 100 KeV. We have established a hard X-ray optics laboratory for development of hard X-ray mirror foils consisting of an RF Magnetron Sputtering system, necessary for the multilayer coatings as well as a thermal slumping system necessary to form thin glass substrates in appropriate curved shape required to realize the nested shell Wolter-I conical approximation X-ray optics.

In order to design the multilayer X-ray mirrors and to characterize the fabricated multilayer mirrors with the X-ray reflectivity (XRR) measurements, it is necessary to have an efficient algorithm that calculates the X-ray reflectivity as a function for a given set of parameters and geometry. In this context, we have developed a program DarpanX which has been implemented as an external model in the popular X-ray spectral fitting software such as XSPEC and ISIS. This allows a very efficient fitting of the measured XRR data using advanced fitting methods such as genetic algorithms and Markov Chain Monte Carlo (MCMC) as well as parallel processing capabilities of these fitting engines. DarpanX code is validated experimentally by employing it in the analysis of X-ray reflectivity measurements of single (Si and W ) and multilayer (W/B 4 C) thin film samples. (see Figure no. 30).

The XRR measurements were carried out at Space Application Center in collaboration with M. R. Patel, C. Karmaker and R. B. Upadhyay.

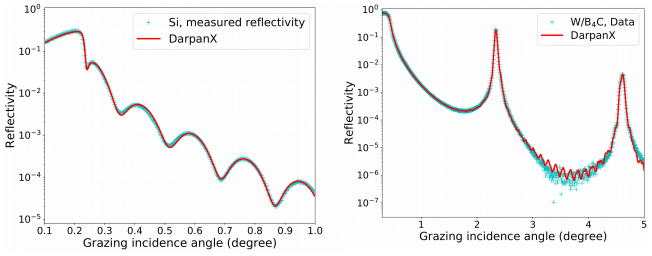


Figure no. 30: XRR reflectivity data(cyan) with IMD model (black) and DarpanX model (red) of (a) Single Si-layer and (b) W/B 4 C multilayer.

**(S. Vadawale, N. P. S.Mithun, B. Mondal, N. K. Tiwari, S. K. Goyal and V. S. Cherukuri)**

# Solar Physics

**Lorentz force evolution reveals the energy build-up processes during recurrent eruptive solar flares**

The energy release and build-up processes in the solar corona have significant implications in particular for the case of large recurrent flares in same active region (AR), which pose challenging questions about the conditions that lead to the episodic energy release processes. It is not yet clear whether these events occur due to the continuous supply of free magnetic energy to the solar corona or because not all of the available free magnetic energy is released during a single major flaring event. In order to address this question, we report on the evolution of photospheric magnetic field and the associated Lorentz force changes in ARs 11261 and 11283, each of which gave rise to recurrent eruptive M- and X-class flares (Figure 1).

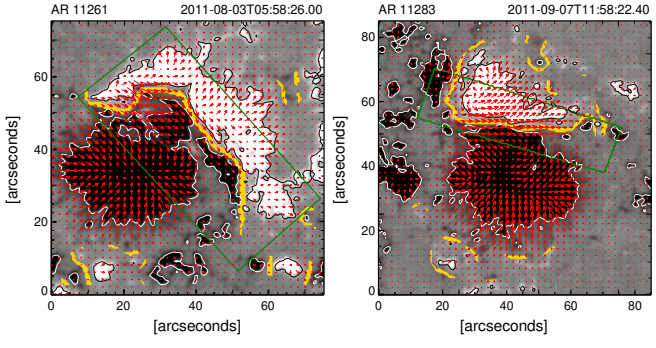


Figure 1.: HMI vector magnetogram of AR 11261 (Left panel) and AR 11283 (Right panel). The radial component (Br) of the magnetic field is shown in gray scale and the horizontal component (Bh) by red arrows, with saturation values $\pm$500 G. The white/black solid line contours the region of negative/positive polarity of Br having a magnitude greater than 500 G. The green rectangular boundary encloses the selected region within which all the calculations have been done. The yellow lines illustrate the polarity inversion line.

Our study reveals that after the abrupt downward changes during each flare, the Lorentz force increases by 2-5$\times10^{22}$ dyne in between the successive flares (see Figure 2). The distinct rebuild-up of net Lorentz force in between the successive flares and its abrupt downward changes during each flare obtained in our study, are the first observational evidence found in the evolution of any non-potential parameter of solar ARs, that confirms the "build-up and release" scenario for magnetic energy storage in the solar corona. We conclude that the recurrent large flares studied in this work occurred due to the newly supplied energy to the AR, instead of consuming the available residual energy. We also have found a correlation between the CME momentum and the associated change in the net Lorentz force, which is consistent with the momentum balance condition for solar flares. In context of space weather predictions, the evolutionary pattern of the net Lorentz force changes reported in this study has significant implications, in particular, for the forecasting of recurrent large eruptive flares from the same AR and hence the chances of interaction between the associated CMEs.

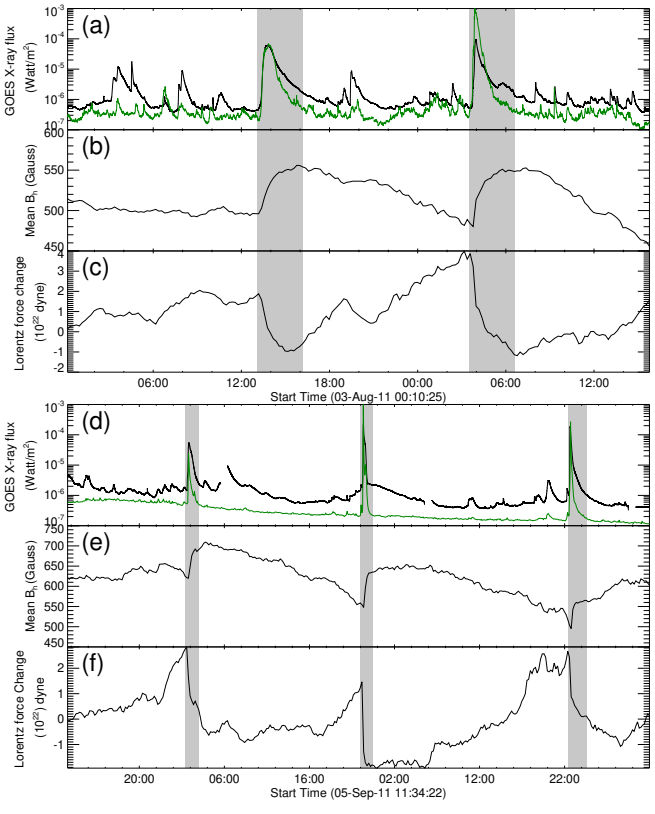


Figure 2.: Temporal profile of the GOES 1-8 Å X-ray flux during the recurrent flares that occurred in AR 11261 (a) and AR 11283 (d). The solid green curves denote the temporal evolution of the brightening calculated within the field-of-view of the AR in the AIA 1600 Å channel. Evolution of the horizontal magnetic field (b and e) and changes in the radial component of the Lorentz force (c and f) within the selected regions (shown by rectangular boxes in Figure 1) of AR 11261 and AR 11283, respectively.

doi : https://doi.org/10.3847/2041-8213/ab4da2

**(R. Sarkar and Nandita Srivastava)**

**Solar filament eruptions as precursors to flareCME events:**

**Establishing the temporal connection**

Solar filaments are dark thread like feature observed in the solar chromosphere. It is believed that there is a connection between filament eruptions and other eruptive phenomena on the Sun such as flares and Coronal Mass Ejections (CMEs). These highly energetic events (Flares and CMEs) have a huge influence on space weather, hence this is important to study from the perspective of space weather forecasting.

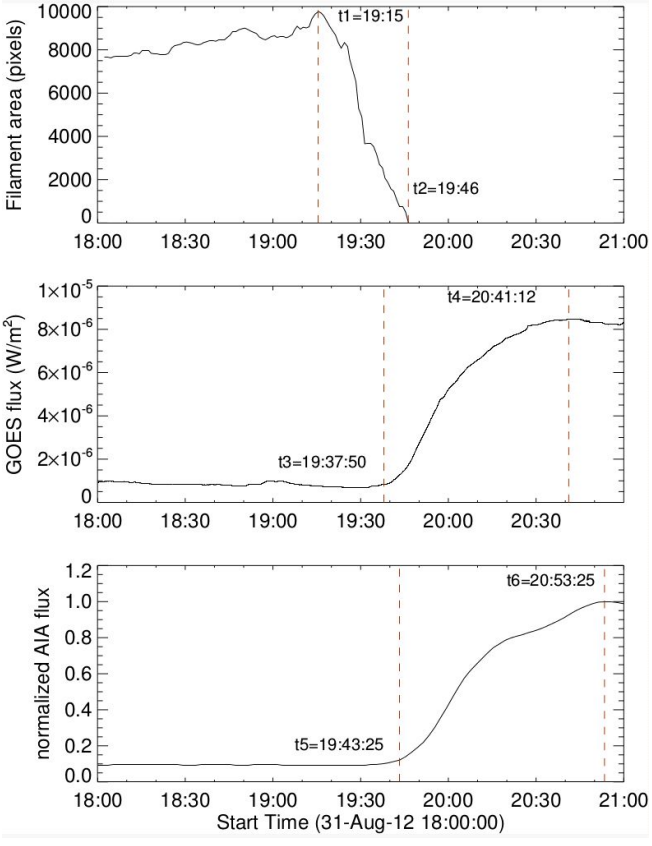


Figure 3.: The top panel shows the evolution of eruptive filament area with time as estimated from H$\alpha$ full disk images taken on 31 Aug 2012. The time t1 and t2 represent the initiation and end time of filament eruption. The middle panel represents the GOES flux over time, where t3 and t4 denote the rise and peak time of GOES X-ray flux respectively. The bottom panel shows the AIA EUV flux captured in 94 Å channel and integrated over the ROI; t5 and t6 indicate the rise and peak time of the EUV flux.

We have used an automated filament tracking algorithm on GONG H$\alpha$ images to explore the temporal connection between the eruptive filaments and the initiation dynamics of solar flare-CME events. Filament eruption start time is defined as the time from which the filament area starts to decrease as observed in H$\alpha$ images. We studied 33 filament eruption events. By analyzing the time delay of the extreme ultraviolet brightening of solar flares relative to the start time of associated filament eruption, we show that in 83% of cases, filament eruption precedes the flare brightening (c.f., Figure 3). In general CME occurs within 2 hr from the start time of the filament eruption. Therefore filament eruption can be considered as a key indicator of any upcoming flare and CME. We have also studied the area decay rate of filaments during their eruption phase and found a good correlation (0.75) between area decay rate of the quiescent filaments and the speed of the associated CMEs. This study would be useful for space weather assessment and characterization based on automated trackers of solar filament dynamics.

This work has been done in collaboration with Suvadip Sinha and Dibyendu Nandy from CESSI, IISER, Kolkata.

doi : https://doi.org/10.3847/1538-4357/ab2239

**(Nandita Srivastava)**

**Preflare processes, flux rope activation, large-scale eruption, and associated X-class flare from the active region NOAA 11875**

We present a multiwavelength analysis of the eruption of a hot coronal channel associated with an X1.0 flare (SOL2013-10-28T02:03) from the active region NOAA 11875. EUV images at high coronal temperatures indicated the presence of a hot channel (indicated by the red arrow in Figure 4) at the core of the active region from the early preflare phase evidencing the preexistence of a quasi-stable magnetic flux rope.

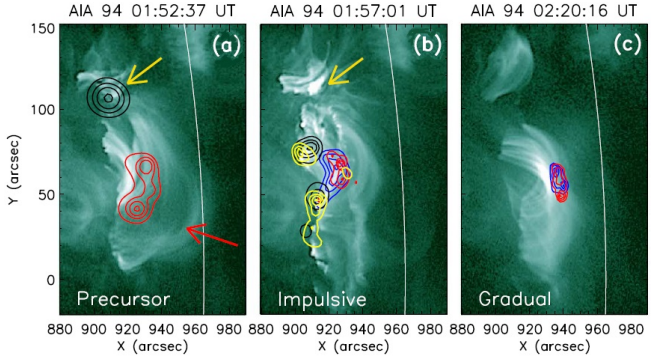


Figure 4.: AIA 94 Å images during different phases of the X1.0 flare. The yellow and red arrows indicate precursor activity and the hot channel, respectively. Co-temporal RHESSI contours of 6-12 keV (blue), 12-25 keV (red), 25-50 keV (yellow), and 50-100 keV (black) energy bands are over-plotted. The contour levels are 30%, 50%, 70%, and 95% of the corresponding peak fluxes.

The hot channel underwent an activation phase after a localized and prolonged preflare event occurring adjacent to one of its footpoints (shown by the yellow arrows in Figure 4). Subsequently, the flux rope continued to rise slowly for ≈16 minutes during which soft X-ray flux gradually built-up characterizing a distinct precursor phase. The flux rope transitioned from the state of slow rise to the eruptive motion with the onset of the impulsive phase of the X1.0 flare. The eruptive expansion of the hot channel is accompanied by a series of type III radio bursts (Figure 5) in association with the impulsive rise of strong hard X-ray nonthermal emissions that included explicit hard X-ray sources of energies up to ≈50 keV from the coronal loops and ≈100 keV from their footpoint locations (see Figure 4). Our study contains evidence that preflare activity occurring within the spatial extent of a stable flux rope can destabilize it toward eruption. Solar eruptions are closely associated with metric and DH type II radio bursts. In this view, the CALLISTO spectrograph stationed at the USO/PRL campus is expected to provide useful information regarding solar eruptions.

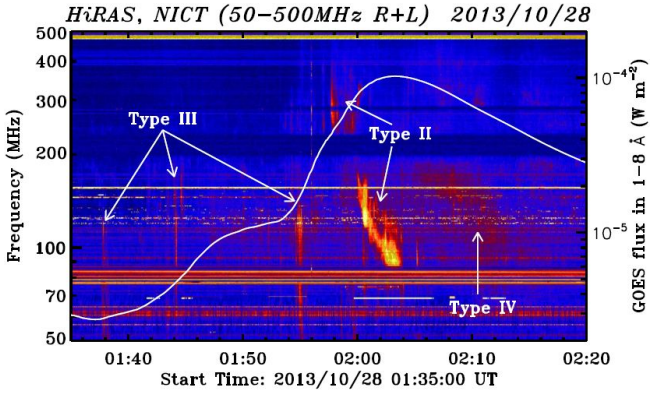


Figure 5.: Dynamic radio spectrum recorded by the HiRAS, showing many discrete type III, a split-band harmonic of type II and a faint type IV spectra. For reference, we have overplotted GOES SXR flux variation in the 18 Å range by the white curve.

doi : https://doi.org/10.3847/1538-4357/ab3a96

**(P. K. Mitra and B. Joshi)**

**Identification of pre-flare processes and their possible role in driving a large-scale flux rope eruption with complex M-class flare in the active region NOAA 12371**

Often, a flare is preceded by pre-flare (and/or precursor) phases where small-scale energy release can be observed in mostly soft X-ray (SXR), extreme ultra-violet (EUV), and optical wavelengths. In this work, we show how a series of small-scale precursor activities lead to the destabilization of a meta-stable flux rope which is analogous to the 'Domino effect'.

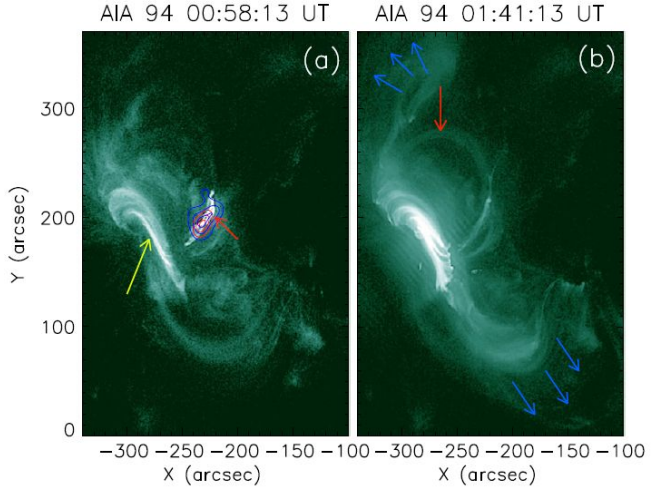


Figure 6.: Panel (a): AIA 94 Å images of AR NOAA 12371 showing the activated hot channel and the adjacent precursor activity (indicated by the yellow and the red, respectively). Panel (b): The moving flash that triggered the eruption of the hot channel (long the arc indicated by the red arrow). The eruption of the hot channel is shown by the blue arrows. The contours in panel (a) represent RHESSI X-ray sources in 6-12 keV (red) and 12-25 keV (blue) bands.

Our observation suggests that the active region underwent a prolonged phase of flux enhancement followed by a relatively shorter period of flux cancellation prior to the onset of the flare which led to the buildup and activation of a hot channel (shown by the yellow arrow in Figure 6(a)). Non-linear force free extrapolation results reveal a set of twisted flux rope co-spatial to the hot channel (sky colored lines in Figure 7). Our analysis reveals strong, localized regions of photospheric currents of opposite polarities at the adjacent precursor location (the location of the pink lines in Figure 7), thereby making the region susceptible to small-scale magnetic reconnection. Precursor reconnection activity from this location (shown by the red arrow in Figure 6(a)) induced a slipping reconnection in the yellow lines shown in Figure 7. This slipping reconnection was observed as a moving flash along a semicircular arc from the precursor location towards the northern leg of the hot channel (indicated by the red arrow in Figure 6(b)) which led to the destabilization of the flux rope (shown by the blue arrows in Figure 6(b)).

This work has been done in collaboration A. Prasad from The University of Alabama in Huntsville, USA.

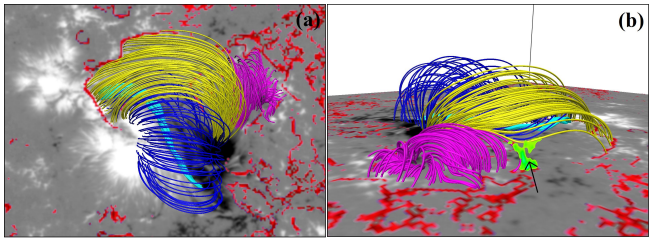


Figure 7.: Model coronal field lines showing the pre-flare configuration of AR NOAA 12371 from top (panel (a)) and side (panel (b)) views. The arrow in panel (b) indicates a quasi-separatrix layer. The red areas in the background are characterized by high Q-values which is susceptible for slipping reconnection.

doi : https://doi.org/10.1007/s11207-020-1596-2

**(P. K. Mitra and B. Joshi)**

**On the spontaneous generation of three-dimensional magnetic nulls**

Solar transients are well known to be the consequences of the fundamental process called magnetic reconnection (MR). The location of MR is hence important to study to get insight into the energetics of these outbursts. Magnetic null points are the preferential sites for MR to occur. To understand the generation of these null points in solar corona like environment, in this work, we have reported two plausible cases. In first, we have deformed one potential three-dimensional (3D) null point with sinusoidal flow. Using this deformed field as the initial state, the plasma is relaxed with the dissipation of magnetic and kinetic energies via MR and viscous dissipation. Consequently, a current carrying null is generated at the the end of the evolution. Secondly, we have considered a modified Arnold-Beltrami-Childress (ABC) magnetic field as the initial state, which is a combination of sine and cosine functions, yet satisfying the solenoidality. The uniqueness of this ABC field lies in its formulation as it has chaotic nature, a non-zero Lorentz force and importantly no null points within the computational volume. The Lorentz force

serves the purpose of driving the magnetofluid from initial state. Interestingly, like the first case, multiple 3D nulls are generated at the end of the relaxation process. Three snapshots are shown in the Figure 8 depicting the whole relaxation process of the modified ABC field. Therefore, the spontaneous development of ordered magnetic structures as 3D nulls from a chaotic system, being one characteristic of self-organized structures, suggests their ubiquity in solar corona. All these simulations are performed using Vikram-100 HPC facility at PRL.

This work has been done in collaboration with P. K Smolarkiewicz(National Center for Atmospheric Research, Boulder, CO, USA), S. Kumar (Patna University, India), & A. Prasad (The University of Alabama in Huntsville, USA)

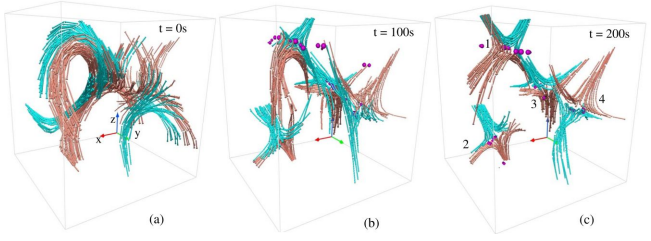


Figure 8.: The chaotic magnetic field lines in cyan and peach color in panel (a) represent the initial state without any three-dimensional magnetic null. The panels (b) and (c) represent the spontaneous development of three-dimensional magnetic nulls from the chaotic field as self-organized states when the system relaxes towards a quasi-steady state at t = 200s. The null points are marked as 1,2,3 and 4 in panel (c). The low magnetic field strength near the null point is highlighted by pink color iso-value.

doi : https://doi.org/10.3847/1538-4357/ab75bb

**(S. S. Nayak, R. Bhattacharyya)**

**On the variation of solar coronal rotation using SDO/AIA observations**

We report on the variability of rotation periods of solar coronal layers with respect to temperature (or, height). For this purpose, we have used the observations from Atmospheric Imaging Assembly (AIA) telescope on board Solar Dynamics Observatory (SDO) space mission of National Aeronautics and Space Administration (NASA). The images used are at the wavelengths: 94, 131, 171, 193, 211, and 335 Angstroms during the period from 2012 to 2018. Analysis of solar full disk images obtained at these wavelengths by AIA is carried out using flux modulation method. Seventeen rectangular strips/bins at equal interval of 10 degrees (extending from 800S to 800N) are selected to extract a time series of extreme ultraviolet (EUV) intensity variations to obtain auto-correlation coefficient. The peak of Gaussian fit to first secondary maxima in the auto-correlogram gives synodic rotation period. Our analysis shows the differential rotation with respect to latitude as well as temperature (or, height). In the present study, we find that the sidereal rotation periods of different coronal layers decrease with increasing temperature (or, height). Average sidereal rotation period at the lowest temperature ($\sim$ 600000 Kelvin) corresponding to AIA-171 Angstrom which originates from the upper transition region/quiet corona is 27.03 days. The sidereal rotation period decreases with temperature (or, height) to 25.47 days at the higher temperature ($\sim$ 10 million Kelvin) corresponding to the flaring regions of solar corona as seen in AIA-131 Angstrom observations (c.f., Figure 9).

Earlier studies employing global helioseismology have reported a considerable decreasing trend of average rotation rate from the interior of the Sun outward to the photosphere. It is to be noted that in this case the temperature decreases from the solar interior on moving upward in the photosphere. Thus, it appears that the rotation of the solar interior and its atmosphere are linked to show a similar variation with temperature.

This work has been done in collaboration with Jaidev Sharma and Anil Malik of CCSU, Meerut and H.O. Vats of SERF, Ahemedabad.

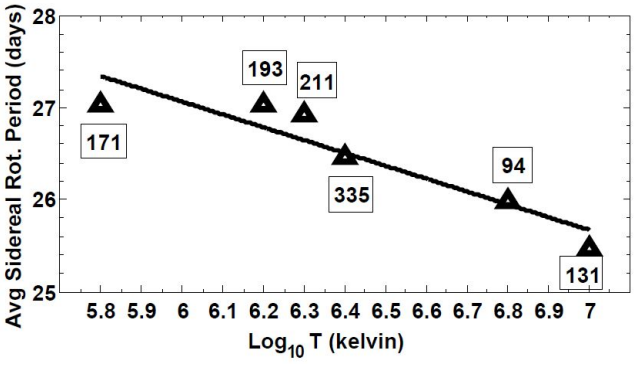


Figure 9.: The plot shows the overall trend (yearly averaged over the period 2012-2018) in sidereal rotation period (days) with respect to temperature (or, height) in the solar atmosphere.

doi : https://doi.org/10.1093/mnras/staa188

**(B. Kumar)**

**Interplanetary coronal mass ejections (ICMEs) during solar cycles 23 and 24: Sun-Earth propagation characteristics and consequences at the near-Earth region**

This work encompasses the ICME activity that occurred during Solar Cycles 23 and 24 (1996-2017) while presenting an overall picture of ICME events during the complete Solar Cycle 24 for the first time. The importance of this study further lies in comparing two subsets of ICMEs, i.e. magnetic clouds (MCs) and ejecta (EJ), to explore how the observed structures of ICMEs at 1 AU could be associated with the properties of CMEs during their launch at the Sun. We found that, although a significant reduction in the number of ICME events in Solar Cycle 24 compared to the previous cycle, the fraction of MCs was much higher during Cycle 24 than Cycle 23 (60% versus 41%, c.f., Figure 10). A combination of multiple parameters affect the evolution of ICMEs, such as CME properties at the near-Sun region (e.g. speed, acceleration, and structure) along with changes in the background solar wind. The CME propagation from the Sun to the

near-Earth environment shows an overall positive as well as negative acceleration (i.e. deceleration), although the acceleration is limited to only low-speed CMEs that are launched with speeds comparable with or less than that of the mean solar wind speed, i.e. ≈400-450 km $s^{-1}$ (c.f., Figure 11).Within a given cycle, the similarities of MC and EJ profiles with respect to the CMEICME speed relation as well as interplanetary acceleration support the hypothesis that all CMEs have a flux rope structure and that the trajectory of the CMEs essentially determines the observed ICME structure at 1 AU.

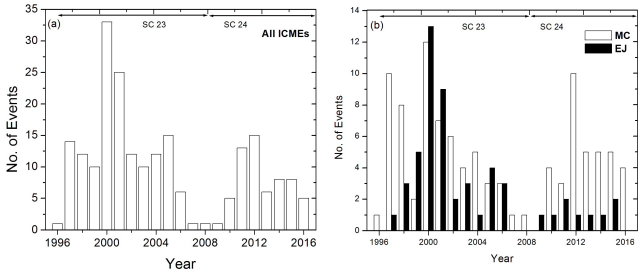


Figure 10.: (a) Histograms showing the annual occurrence of ICMEs and, (b) Two types of ICMEs, i.e. MCs (white bar) and EJs (black bar), during Solar Cycles 23 and 24.

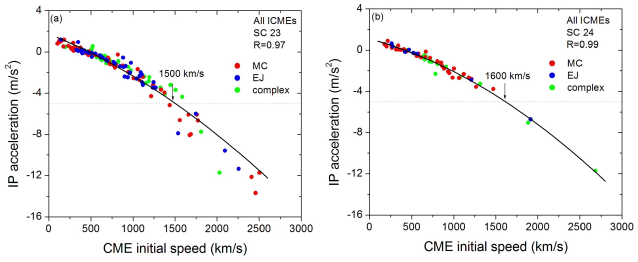


Figure 11.: Relation between the initial CME speeds and the interplanetary (IP) accelerations for all ICMEs during (a) cycle 23 and (b) cycle 24. We have drawn a dotted horizontal line at an arbitrary acceleration value of -5 $ms^{-2}$ to compare the acceleration profiles during the two cycles.

doi : https://doi.org/10.1007/s11207-019-1443-5

This work has been done in collaboration K. S. Cho, R. S. Kim (Korea Astronomy and Space Science Institute, South Korea), Y. J. Moon (School of Space Research, Kyung Hee University, South Korea).

**(Syed M. Ibrahim, B. Joshi)**

# Planetary Sciences

## Modelling of Planetary Atmosphere, Simulations and Interstellar Medium

### Retrieval of Martian ozone and dust from SPICAM spectrometer for MY27-MY28

Ozone ($O_3$) is important in the stabilization of $CO_2$ in the Martian atmosphere and thus it is important to study the spatio-temporal variability of $O_3$. We have retrieved $O_3$ columnar abundances and dust for MY27-MY28 from raw spectral radiances recorded by SPICAM (SPectroscopy for the Investigation of the Characteristics of the Atmosphere of Mars) onboard Mars Express. This required the setting up of a forward radiative transfer model. We have also run the photochemistry coupled LMD-GCM on our HPC cluster, to simulate $O_3$, carbon monoxide and water vapor. The seasonal variability is studied in tropical, mid and high latitudes and is compared with simulations by the GCM.

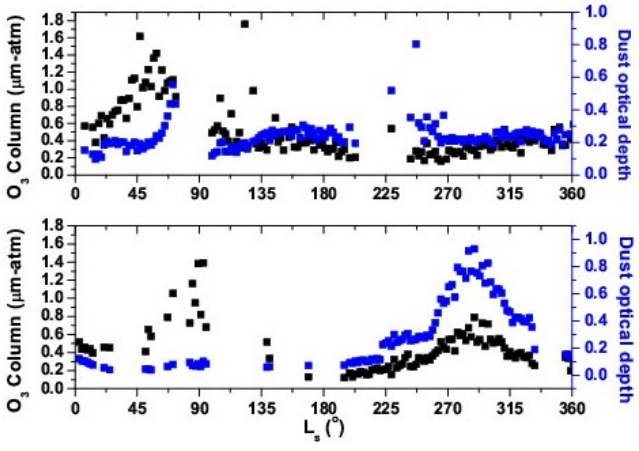


Figure 1: Correlation of ozone and dust retrieved from observations by SPICAM, for the region 0°-30°S, for MY 27 (upper panel) and MY 28 (lower panel).

Seasonal variations in $O_3$ are not prominent in tropical latitudes, with $O_3$ column values observed in this region below 10$\mu$m-atm. The high latitudes exhibit the largest seasonal variations in $O_3$, with a winter high and a summer low and comparison with GCM results is good in general. An ozone-water vapor anti-correlation is seen at high latitudes, as reported by earlier studies. We have studied the correlation of $O_3$ with dust, retrieved simultaneously from SPICAM observations. In southern tropical latitudes, the columnar $O_3$ is seen to increase during a global dust storm year (MY 28) compared to the $O_3$ column values during a year without global dust storm (MY 27), though the water vapor column between these years remains unchanged. This indicates towards the radiative impact of dust on $O_3$ and its retrieval. The increase of $O_3$ can be as high as 50% of the $O_3$ without global dust storm. A similar result can be seen in $O_3$ simulated by the LMD-GCM for the dark dust storm of MY 28. To study the effect of dynamics on $O_3$ columnar abundance, correlation of GCM simulated CO and $O_3$ have been analysed. The dynamical contribution to the $O_3$ column is found to be highest during winter over the southern polar region, due to the transport of O atoms ($O_3$ column can increase from 3 to 27 $\mu$m-atm due to the dynamical effect). On the other hand, in the northern polar region, the dynamical contribution is much less than the chemical contribution, while over the equator and tropical region, the dynamical effect is insignificant.

doi : https://doi.org/10.1007/s12040-019-1167-9

**(V. Sheel and A. Modak)**

### Competing pathways in odd oxygen photochemistry of the Martian atmosphere

Though the photochemistry of Mars is comparatively simple, the orbital properties of Mars and its exposure to solar influx lead to pronounced seasonal and latitudinal variations of short lived species (trace gases). We have a fair understanding of such species, such as ozone, that determine the equilibrium state of the Martian atmosphere. However, we lack in understanding the relative importance of various production and loss processes, in determining the abundance of ozone and related trace species. To fill this void, we use the photochemistry coupled LMD GCM to study in detail the important source and sink processes of odd oxygen (ozone and oxygen atoms) and their contribution in different locations and seasons. This becomes especially important due to the high seasonal variability of water vapor involved in the photochemistry. The study shows few interesting features about the processes. The loss due to OH peaks above 50km irrespective of season but the peak value increase during perihelion season due to increased availability of water vapor in the heights. Contrary to expectations, the day time loss rates due to $HO_2$, which is the most significant loss of odd oxygen, do not show a strong seasonal variation. $O_x$ is in photochemical equilibrium up to about 30 km in the aphelion season and up to 45 km in the perihelion season. In the photochemical equilibrium domain, $HO_2$+O is the dominant loss process of $O_x$, while above this domain, the $HO_x$+O, H+$O_3$ and O+O reactions have comparable contributions to the $O_x$ loss. The O+$O_3$

reaction is always a minor contribution to the $O_x$ loss. We observe that the seasonal variability of ozone is broadly connected to the height of the hygropause. For eg., over northern polar region during aphelion season, water vapor saturates above 20km. Thus, destruction of odd oxygen due to catalytic $HO_x$ radicals remains mostly bound to the lower atmosphere.

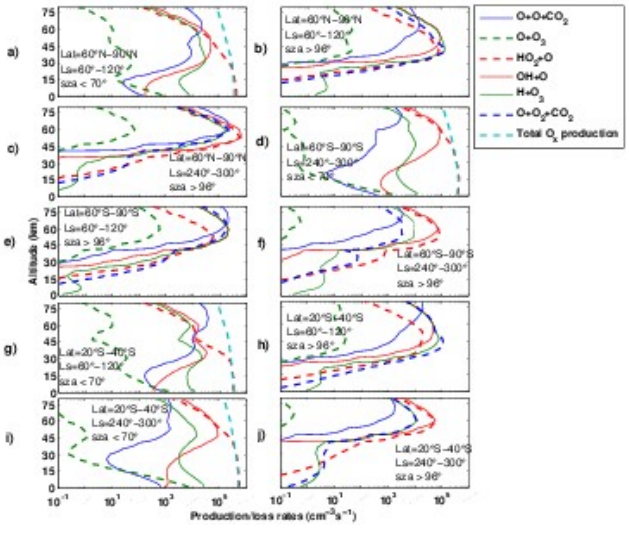


Figure 2: Comparison among the production and loss rates of $O_x$ during the aphelion season (Ls=60°120°) and the perihelion season (Ls=240°300°) over the latitude region 60°N90°N, 60°S90°S and 20°S40°S. Panels with Solar Zenith Angles (SZA) $< 70°$ correspond to daytime values, while those with SZA $> 96°$ correspond to nighttime values.

doi : https://doi.org/10.1016/j.pss.2019.104783

**(V. Sheel and A. Modak)**

### Tangential winds of a vortex system in a planetary surface layer

Though complex numerical models are available, it is challenging to derive simple estimates to accurately determine the tangential wind velocities for a vortex system such as dust devil, tornado, and storms. On Mars dust devils play an important role to inject dust grains into the atmosphere. In the Martian planetary boundary layer PBL, surface can force convective vortices leading to dust devils. We use the Navier Stokes equations and the continuity equation to give an analytical expression for the mean (with respect to time) tangential wind velocity in cylindrical co-ordinate system within the surface layer of a planetary atmosphere. We utilize Martian surface layer properties for theoretical derivation of our solution. However, our results remain valid for any planetary surface layer as long as all of our assumptions are valid. Our theoretical values of the tangential wind velocity (10-16 ms$^{-1}$), lie well within the range of observed values. The derived equation represents the dependency of tangential velocity on both radial distances from the center of vortex, and the altitude. As we move further away from the vortex center the effect of vortex becomes non-significant, and velocities start following the standard logarithmic profile. Due to dependency of tangential wind velocity on altitude the tangential velocity increases as we move higher up in the vortex system. At 100 m altitude, for an order of magnitude increase in the radial distance, the mean tangential wind velocity drops by about a factor of 1.5 in magnitude.

doi : https://doi.org/10.1007/s12040-019-1268-5

**(V. Sheel, S. Uttam and D. Singh)**

### SEP electron acceleration in the upper ionosphere of Mars: MAVEN observation

Recently, Mars Atmosphere and Volatile Evolution (MAVEN) have observed three kinds of auroras at Mars: (1) discrete aurora, (2) proton aurora, and (3) diffuse aurora in the atmosphere of Mars.

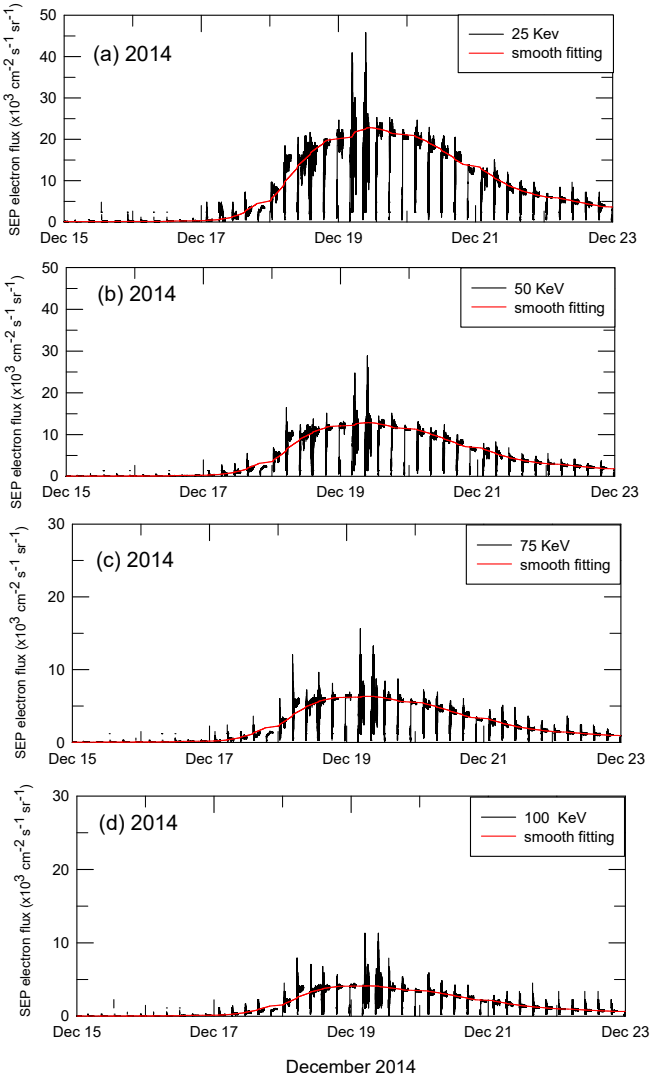


Figure 3: A time series of SEP electron fluxes at energies 25 keV (a), 50 keV (b), 75 keV (c) and 100 keV (d) as observed by SEP instrument onboard MAVEN during 15-23 December, 2014.

We have modeled excitation processes and emission intensity of diffuse aurora that occurred between 17 and 21 December 2014 due

to precipitation of Solar Energetic Particles (SEPs) in the nighttime atmosphere of Mars. The diffuse aurora is observed at about 70 km by Imaging Ultraviolet Spectrograph (IUVS) instrument onboard MAVEN. The figures 3(a-d) shows the time series of electron spectra at energies 25 keV, 50 keV, 75 keV, and 100 keV, observed by SEP instrument onboard MAVEN from 15 to 23 December, 2014. During this period, MAVEN completed 48 periapse passes between orbits # 408 to # 456. We have plotted the SEP electron fluxes without averaging over the orbit (thus all the data of periapsis pass are plotted for every orbit). The solid red line represents smooth fitting obtained from Smooth Data Moving Average Filter technique (https://mathworks.com/help/curvefit/smooth.html/). The large enhancements in the SEP electron spectra have been observed in presence of diffuse aurora. These spectra observed maximum electron fluxes $\sim$ 2.4 x $10^4$, 1.3 x $10^4$, 7.0 x $10^3$ and 5.1 x $10^3$ $cm^{-2}$ $s^{-1}$ $sr^{-1}$ at energies 25 keV, 50 keV, 75 keV and 100 keV respectively. The SEP peak electron fluxes are decreasing with increasing energy. We have used these fluxes in our calculation of diffuse auroral emissions. It has been found that 100 keV electron is enough to produce the peak emission intensity of diffuse aurora at about 70 km.

doi : https://doi.org/10.1029/2019JA026688

**(S.A. Haider and J. Masoom)**

**Auroral production rate in the nighttime ionosphere of Mars**

We have modeled ion production rates of $CO_2^+$, $N_2^+$, and $O^+$ due to precipitation of auroral electrons and proton-hydrogen ($H^+$-H) atoms in the nighttime ionosphere of Mars.

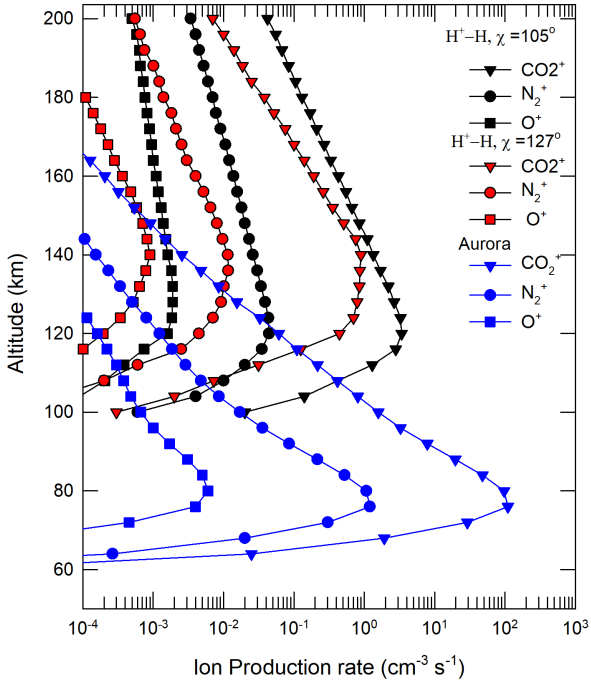


Figure 4: The ion production rates of $CO_2^+$, $N_2^+$ and $O^+$ due to impact of auroral electrons and $H^+$-H impact at SZA=105° and 127° in the nighttime ionosphere of Mars.

In this calculation we have used Hybrid model and Yield spectrum methods based on Monte Carlo approach. The $H^+$-H is a product of energetic neutral atom H and proton $H^+$. In the Hybrid model the $H^+$-H flux and ion production rates are estimated simultaneously. The $H^+$ and H are accelerated up to energies 10 keV in presence of electric and magnetic fields. The Yield spectra also calculate auroral electron flux and production rates simultaneously. The $H^+$-H and auroral energetic electrons are precipitating together into the atmosphere of Mars. The figure 4 shows a comparison between ion production rates of $CO_2^+$, $N_2^+$, and $O^+$ due to impact of auroral electrons and $H^+$-H fluxes at solar zenith angle (SZA), $\chi$ = 105° and 127°. The $H^+$-H impact ionization rates are decreasing with increasing $\chi$. The upper ionosphere of Mars is formed between altitudes 100 km and 200 km due to $H^+$-H impact ionizations. The auroral ionosphere is formed in the middle ionosphere of Mars due to impact of 100 keV electrons between altitude 50 km and 100 km. The auroral ion production rates are larger by one to two orders of magnitude than that produced by $H^+$-H impact ionization.

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**(S. A. Haider and Y. S. Siddhi)**

**Effects of solar flares in the upper ionosphere of Mars**

Responses of solar X-ray flares were observed in a layer of the Martian ionosphere at altitudes of $\sim$110 km from 32 electron density profiles obtained by radio science experiment onboard Mars Global Surveyor (MGS) during solar cycle 23. Of the 32 profiles recorded during flare periods, 10 were associated with X-class flares, 12 with M-class and 10 with C-class flares. The flare E-peak densities vary with solar X-ray flux, SZA, Solar Longitude (Ls) and latitudes. Ionospheric Electron Content (IEC) and E-peak electron production rates of these flare profiles are estimated in the E region ionosphere. In figure 5 (left panel), we have shown % increase in IEC at different UT for X, M, and C class flares as observed by MGS. In figure 5 (right panel), % increase in the corresponding solar X-ray fluxes are shown at different UT for the flares as observed by GOES 10 at peak flare time. It is found that the ionosphere of Mars was calm before the solar flares. The percentage increases in the X-ray flux are maximum for X14.4, M9.3 and C9.5 types of solar flares at 13:50 UT, 02:24 UT and 10:24 UT respectively. After the solar flares the Martian ionosphere was strongly perturbed. The decay time of the flare is more than the rise time of the flare. Therefore, the effects of X-ray flares are continued for a longer time up to $\sim$ 2 h or some times more in the E region ionosphere. It should be noted that the electron densities are not measured at the peak flare time. The measurements of the electron densities were available only during the decay phase of the flares. In comparing between figure 5 ac and figure 5 df we have found a direct correlation between percentage increases of GOES X-ray fluxes and IEC for X, M and C class flares at different UT. The percentage increase in IEC are maximum on 15 April 2001, 31 May 2003 and 19 December 2000 for X14.4, M9.3 and C9.5 types of the flare in figure 5 a-c respectively.

This work was completed at PRL, when P. Thirupathaiah was a PDF. He is now at Department of Physics, University of Petroleum and Energy Studies, Dehradun, India

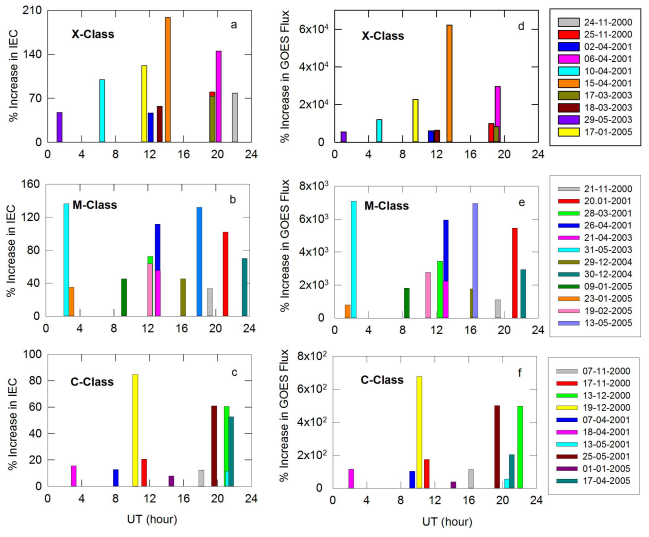


Figure 5: Left panel: The % increase in IEC at different UT for 10 X-class (a), 12 M-class (b) and 10 C-class (c) flare profiles as observed by MGS. Right panel: The % increase in corresponding solar X-ray fluxes at different UT for 10 X- class (d), 12 M-class (e) and 10 C-class (f) flares as observed by GOES 10 at peak flare time.

doi : https://doi.org/10.1016/j.icarus.2019.04.015

**(P. Thirupathaiah, Y. S. Siddhi, S. A. Haider and K. Durga Prasad)**

**Model for forbidden atomic carbon, nitrogen, and oxygen optical emission lines in the water-poor comet C/2016 R2 (Pan-STARRS)**

Contrary to the many comets observed so far, various ground-based observations of comet C/2016 R2 (Pan-STARRS) (hereafter C/2016 R2) have shown that this comet has a unique composition, with a large amount of CO, $N_2$, and remarkably depleted in $H_2O$. We reanalyzed the high-resolution spectra of comet C/2016 R2 obtained in February 2018 using the UVES spectrograph of the European Southern Observatory Very Large Telescope, where various forbidden atomic emission lines of [CI], [NI], and [OI] were observed in the optical spectrum of this comet when it was at 2.8 AU from the Sun. We explored the associated photochemistry of parent species, which produces different metastable states and forbidden emissions. The observed forbidden emission intensity ratios are studied in the framework of a coupled-chemistry emission model. The model calculations show that $CO_2$ is the major source of both atomic oxygen green and red-doublet emissions in the coma of C/2016 R2 (while for most comets it is generally $H_2O$), whereas, CO and $N_2$ govern the atomic carbon and nitrogen emissions, respectively. Our modeled oxygen green-to-red-doublet emission ratio is close to what is seen in observations when we consider $O_2$ abundance with a production rate of 30% relative to the CO. We constrained the mean photodissociation yield of CO, producing C($^1$S) at about 1%, a quantity which has not been measured in the laboratory. The collisional quenching is not a significant loss process for N($^2$D) though its radiative lifetime is significant ($\sim$10 h). Hence, the observed [NI] doublet-emission ratio ([NI] 5198/5200) of 1.22, which is smaller than the terrestrial measurement by a factor 1.4, is mainly due to the characteristic radiative decay of N($^2$D). Following case studies were carried out as shown in the Figure 6: Case-A: Using the standard atomic and molecular parameters of various oxygen-bearing species; Case-B: 30% $O_2$ relative abundance with respect to CO production rate; Case-C: $CO_2$ photodissociation cross section producing O($^1$D) is increased by a factor of three; Case-D: Using the standard atomic and molecular parameters of various carbon and nitrogen-bearing species; Case-E: CO photodissociation cross section producing C($^1$D) is decreased by a factor of four; Case-F: the photodissociative excitation cross section of $N_2$ producing N($^2$D) is increased by a factor of three.

This work is done in collaboration with D. Hutsemékers, C. Opitom, E. Jehin, and J. Manfroid, of STAR Institute, University of Liège, Belgium, and European Southern Observatory, Santiago, Chile.

doi : https://doi.org/10.1051/0004-6361/201936713

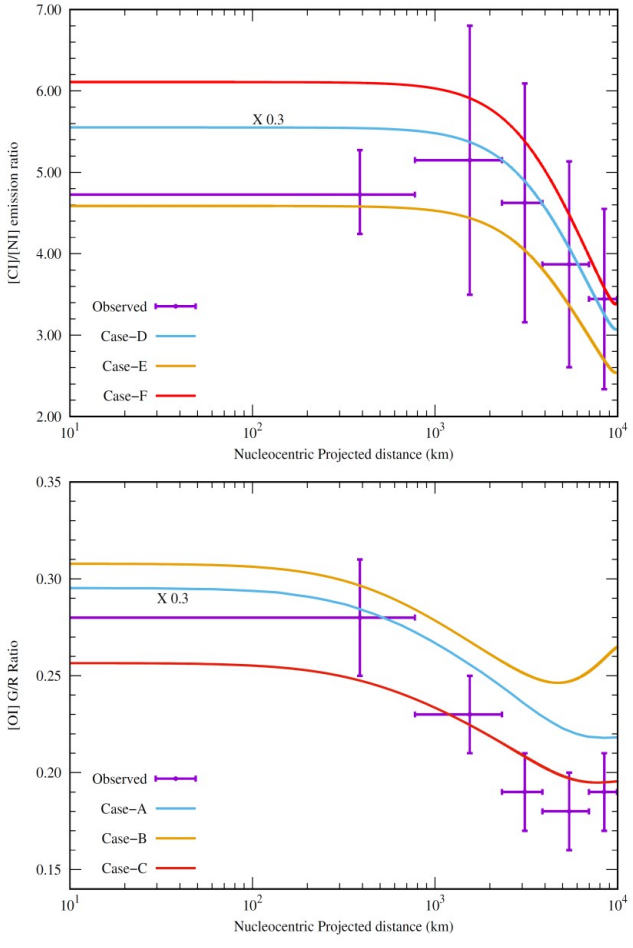


Figure 6: Comparison between modeled and observed [CI] to [NI] (top panel) and [OI] Green/Red (bottom panel) emission ratios in comet C/2016 R2. The observed emission ratios are plotted with error bars. The calculated emission ratios for Case-A and Case-D are plotted after multiplication by a factor of 0.3.

**(S. Raghuram and A. Bhardwaj)**

**A photochemical model for ultraviolet atomic line emissions in comet 67P/Churyumov-Gerasimenko**

Alice ultraviolet spectrometer onboard Rosetta mission observed several spectroscopic emissions emanating from volatile species of comet 67P/Churyumov-Gerasimenko (hearafter 67P/C-G) during its entire escorting phase. Assuming electron impact is the only excitation source, the initial Alice observed emission intensities are used to derived electrons densities in the cometary coma when the comet was around 3 AU pre-perihelion. We have developed a photochemical model for comet 67P/C-G to study the atomic hydrogen (HI 1216, 1025, & 973 Å), oxygen (OI 1152, 1304, & 1356 Å), and carbon (CI 1561 & 1657 Å) line emissions by accounting for major production pathways. We have quantified the percentage contributions of photon and electron impact dissociative excitation processes to the total intensity of the emission lines, which has an important relevance for the analysis of Alice observed spectra.

We showed that photodissociative excitation processes are more significant compared to electron impact in determining the atomic emission intensities in comet 67P/C-G when it was at 1.56 AU from the Sun and had a gas production rate of about $10^{27}$ $s^{-1}$. Based on our model calculations, we suggest that the observed atomic hydrogen, oxygen, and carbon emission intensities can be used to derive $H_2O$, $O_2$, and CO, abundances, respectively, rather than electron density in the coma of 67P/C-G. The calculations shown in the Figure 7 are done by varying $H_2O$ production rate ($QH_2O$) between 3.5 and 7 $10^{27}$ $s^{-1}$ and for relative abundances of 2.5, 2, and 4% of $CO_2$, CO, and $O_2$ with respect to water, respectively, when the comet was at 1.56 AU from the Sun.

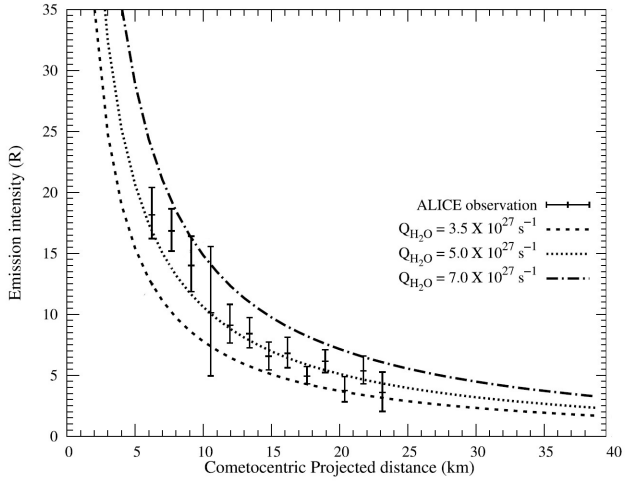


Figure 7: The modelled H I Lyman-alpha emission intensity profile as a function of cometocentric projected distance on comet 67P/C-G. Alice observed H I Lyman-alpha emission intensity on 25 May 2015 is plotted with vertical error bars.

doi : https://doi.org/10.1016/j.icarus.2020.113790

**(S. Raghuram and A. Bhardwaj)**

**The dayside ionosphere of Mars: Comparing a one-dimensional photochemical model with MAVEN Deep Dip campaign observations**

A one dimensional photochemical model for the dayside ionosphere of Mars has been developed for calculating the density profiles of ions and electrons under steady state photochemical equilibrium condition. The study focuses on the Deep Dip campaigns of the Mars Atmosphere and Volatile EvolutioN mission (MAVEN) and used the in-situ measurements of neutral density profiles, solar flux and electron temperatures from instruments onboard MAVEN as input to the model. An energy deposition model is employed for calculating the attenuated photon flux and photoelectron flux at different altitudes in the ionosphere. Volume production rates of major primary ions, $CO^{+2}$, $CO^+$, $O^+$, $C^+$, $N^{+2}$, and $N^+$, due to photon and photoelectron impact are calculated and used as input to the model in which ion-neutral chemistry in the dayside ionosphere is simulated. The modelled ion profiles are compared with the ion mode observations of Neutral Gas Ion Mass Spectrometer (NGIMS) and electron density estimates from Langmuir Probe and Waves (LPW). The model reproduces the observed structure of the major ion profiles $O^{+2}$, $CO^{+2}$, and electron density reasonably well, but is larger by a factor of 2 in magnitude. By reducing the neutral $CO_2$ density, the modelled and observed ion and electron density profiles can be reconciled. The model also calculated the densities of 11 other ions, viz. $N^+$, $C^+$, $O^+$, $NO^+$, $N_2H^+$, $HCO^+$, $N^{+2}$, $CO^+$, $OCOH^+$, $HNO^+$, and $OH^+$, which are compared with the NGIMS observations. Such a comparison for the MAVEN deep dip periods is reported for the first time, which showcases the level of the current understanding of the ion chemistry in the Martian ionosphere.

This work is done in collaboration with Vrinda Mukundan of SPL, VSSC

doi : https://doi.org/10.1016/j.icarus.2019.113502

**(A. Bhardwaj)**

**On the response of Martian Ionosphere to the Passage of a Corotating Interaction Region: MAVEN Observations**

The response of Martian ionosphere to the passage of corotating interaction region (CIR) of June 2015 is studied using observations from several instruments aboard the MAVEN mission. An intense CIR arrived at Mars on 22 June 2015, during which the upstream solar wind and interplanetary magnetic field conditions were monitored by the Solar Wind Ion Analyzer (SWIA), Solar Wind Electron Analyzer (SWEA), Solar Energetic Particle (SEP), and Magnetometer (MAG) instruments aboard MAVEN. The CIR event was characterized by enhancements in solar wind density, velocity, and dynamic pressure, and an increased and fluctuating interplanetary magnetic field associated with enhanced fluxes of Solar Energetic Particles. The MAVEN Langmuir Probe and Waves (LPW) instrument provided the ionospheric observations such as electron density and electron temperature during this period. The dayside ionosphere is significantly compressed only near the peak of solar wind dynamic pressure enhancement ($\sim$14 nPa). In contrast, on the nightside, the electron density remains depleted for a longer period of time.

The electron temperatures are also enhanced during the period of electron depletion on the nightside. The Suprathermal and Thermal Ion Composition (STATIC) measurements show enhanced fluxes of suprathermal heavy ions in the Martian exosphere during CIR period, and evidences for enhanced tailward flow of these pickup ions. The analysis suggests that the nightside ionosphere is primarily controlled by the precipitating Solar Energetic Particles and pickup ions transported across the Martian terminator and depletes significantly when the heavy ion flux in the exosphere enhances.

This work is done in collaboration with C. Krishnaprasad and Smitha V. Thampi of SPL, VSSC.

doi : https://doi.org/10.1029/2019JA026750

**(A. Bhardwaj)**

**Acceleration of Energetic Ions in Corotating Interaction Region near Mars (1.5 AU): Evidence from MAVEN spacecraft**

The dearth of observations between 1 and 3 AU limits our understanding of energetic particle acceleration processes in interplanetary space. We present first-of-their-kind observations of the energetic particle acceleration in a corotating interaction region (CIR) using data from two vantage points, 1 AU (near Earth) and 1.5 AU (near Mars). The CIR event of 2015 June was observed by the particle detectors aboard the Advanced Composition Explorer satellite as well as the Solar Energetic Particle (SEP) instrument aboard the MAVEN spacecraft situated near 1.5 AU. We find that a CIR shock can accelerate a significant number of particles even at 1.5 AU. During this event the acceleration by the shocks associated with the CIR could cause an enhancement of around two orders of magnitude in the SEP energetic ion fluxes in the $\sim$500 keV to 2 MeV range when the observations near 1 and 1.5 AU are compared. To demonstrate the differences between SEP acceleration in CIR and other impulsive events, we show the energetic ion flux observations during an intense coronal mass ejection period in March 2015, in which case the enhanced SEP fluxes are seen even at 1 AU. These observations provide evidence that CIR shock can accelerate particles in the region between Earth and Mars that is, only within the short heliocentric distance of 0.5 AU in interplanetary space.

This work is done in collaboration with Smitha V. Thampi, C. Krishnaprasad, P. R. Shreedevi, Tarun Kumar Pant of SPL, VSSC.

doi : https://doi.org/10.3847/2041-8213/ab2b43

**(A. Bhardwaj)**

**Photoelectron sheath formation, dust levitation and dust dynamics over sunlit lunar regolith**

Sunlight scattering from the electrostatically charged floating particles is considered accountable for the lunar twilight observations of the horizon glow during local sunset and streamers. The exospheric plasma and its composition are maintained under the influence of solar radiation, solar wind plasma, and local plasma. Usually, in the sunlit zone, the lunar surface acquires a positive potential of few volts, and a photoelectron sheath is formed due to dynamic equilibrium between the photoelectrons from and their subsequent accretion over lunar regolith. In comparison to the subsolar point (equator region), a larger photoelectron sheath is predicted near the terminator region (high latitudes); this is consistent with the typical observation. Additionally, a larger sheath span is predicted during active solar events. The electrostatic equilibrium with lunar gravity may support the particle levitation up to a couple of meters altitude. For instance, 200 and 50 nm fine dust particles are predicted to float up to $\sim$10 cm and $\sim$225 cm, respectively, in the lunar photoelectron sheath at 70$^{\circ}$ latitude. However, the static models are found inadequate in explaining the sunlight scattering at high (km) lunar altitudes, as observed in Apollo explorations. We take up this problem and derive the dynamics of the fine charged particles within the photoelectron sheath over the sunlit lunar surface. Based on the analysis, in the normal solar conditions, the sunlit regolith is predicted to acquire a finite positive potential of few volts. It induces an electric field equivalent $\sim$ (58) $\mathrm{Vm}^{-1}$ in the proximity of the lunar surface. The potential and electric field within sheath are estimated significant up to an altitude of a couple of meters. The sheath characteristics have been coupled with dynamical equations of the particle motion and their charging in determining the vertical dynamics (lofting) of the charged particles detached from the lunar regolith. In this framework, the fine grains are shown to exhibit hopping within the sheath. In contrast to the motion solely under lunar gravity, the photoelectron sheath field is noticed to contribute significantly in determining the particle dynamics, particularly the smaller 10s nm grains. For instance, 10 nm particles are anticipated to rise to $\sim$km's lunar altitude, which is consistent with the observations. Literally, it predicts that the charge dust detectors in the lunar orbiting spacecraft may detect $<$ 10 nm positively charged particles in the sunlit regime.

doi : https://doi.org/10.3847/1538-4357/ab3e08

**(S. K. Mishra and A. Bhardwaj)**

**Electrostatic charging of the Moon under extreme plasma conditions**

The lunar surface potential, in general, is a consequence of dynamic equilibrium between the currents associated with the solar plasma irradiation and photoemission flux. This analysis brings out a physics insight of the charging of the lunar regolith, exposed to the extreme ambient plasma corresponding to wake plasma, SEP events, and terrestrial magnetosphere. In dark regions, the lunar surface may attain a negative potential, nearly of the order of the electron temperature in the plasma distribution for low values of the secondary emission yield. Furthermore, unlike the notion of positive potential over the sunlit location, a significant contrast in the charging of the lunar surface, depending on surface and plasma parameters, is predicted, and it may differ by the orders of magnitude. This is consistent with the observation of negative potential above the dayside lunar surface in the terrestrial plasma sheet. The results for the variation in regolith work function and photoefficiency reflects the possible disparity in the adjacent locations in terms of the material composition. A similar difference in the surface charging may occur for the topographical features, for instance, nearby highland and crater locations, where the rear side (i.e., opposite to sun-facing) is shadowed region this may correspond to the smaller reach of solar

photons, and the local plasma is a dominant source of charging. In such a case, the potential in the dark region ($\sim$ 100 V) and adjacent illuminated ($\sim$ few Volt) portions of the Moon regolith may differ by orders of magnitude. In such extreme plasma conditions, the lunar regolith may lead to the differential charging, which might play a significant role in the transportation of local charge and fine charged dust in the lunar atmosphere. The analytical model gives a feasible solution (and scaling) of the surface charging and is of practical implications in conceptualizing the test experiments in labs for future lunar studies.

doi : https://doi.org/10.1007/s10509-020-3740-8

**(S. K. Mishra)**

**Lunar Escape Process**

Dust particles exist everywhere in interplanetary space and they evolve dynamically after their origination from the sources like Asteroid belt, Kuiper belt, comets or space debris left during the formation of solar system. These micrometeorites encounter the inner planets, while they spiral-in towards the Sun. From whichever come to Earth, many particles are ablated in the Earth's atmosphere and leave the metallic ions behind. In case of Moon, all such particles can reach the surface without ablation owing to the absence of atmosphere. Due to the impact of hypervelocity dust particles on lunar surface, ejecta come out in the lunar environment. In some cases, the ejecta velocity could be larger than the escape velocity and particles may be able to escape from Moon. Further, the escaping ejecta may carry water ice (volatiles), whenever incoming projectiles hit the surface in polar region with the water ice present in it. We have computed the ejecta parameters and estimated the possible escape of volatiles from Moon, using Galileo observations of the dust particles near Moon. The model for lunar escape process for the regolith and water ice (volatile) has been suggested for the first time. Considering the distribution of incident angle, the upper limit of regolith escape rate is found to be $\sim$2.218$\times10^{-4}$ [1.662$\times10^{-4}$, 10.232$\times10^{-4}$] kg/s. Similarly, the upper limit of water ice escape rate is found to be $\sim$1.988$\times10^{-7}$ [1.562$\times10^{-7}$, 7.567$\times10^{-7}$] kg/s.

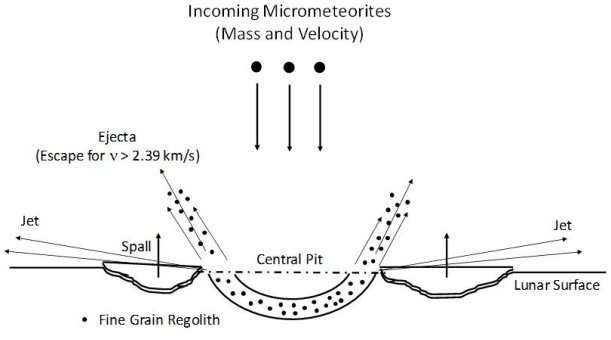


Figure 8: Lunar escape process due to micrometeorite impact on lunar surface.

From our findings, we get the water ice escape rate to be $\sim$6.271 [4.926, 23.863] kg/year. Moon is found to be gradually becoming heavier due to its one order higher incoming dust particles than those escaping from it. Though slowly, Moon could be depleted of water ice resource over a period of time due to micrometeorite impact on the surface. The water ice is a useful source for future manned mission, habitation and as a possible source of hydrogen (as a fuel) for the rockets. The results are useful to understand dust and volatile escape from Moon. In addition, the approach can also be applied to other planetary bodies in the solar system, for understanding the escape process. The micrometeorite impact as well as escape study can be carried out using instruments in future planetary missions. Figure 8 illustrates the scenario on lunar surface due to the bombardment of micrometeorites.

doi : https://doi.org/10.1016/j.icarus.2019.113510

**(J. P. Pabari, S. Nambiar, V. Shah and A. Bhardwaj)**

**Martian Schumann Resonance**

Planetary atmosphere usually has clouds, which are prone to the charge generation and separation phenomena, leading to some spark and avalanche, subsequently. In case of Martian surface, the surface dust is lifted in the environment due to dust storms. Triboelectric effect among the dust particles can give rise to electrostatic discharges and emit the electromagnetic waves in the ELF/VLF range. The waves are bounced back and forth between the surface and conducting layer of the atmosphere, causing the Schumann Resonance to exist. A model for the observable Schumann Resonance is derived and the profiles for Mars are obtained in the heterogeneous cavity. Results convey a possibility of the occurrence of Martian electrical discharges due to a dust layer around twenty kilometer height from the surface.

doi : https://doi.org/10.1016/j.asr.2018.12.006

**(S. A. Haider, J. P. Pabari, J. Masoom and Siddhi Y. Shah)**

**Lightning Generated Whistlers at Venus**

The Venus Express (VEX) mission provided the most recent lightning observations in the form of whistler-mode waves using a dual fluxgate magnetometer. The detection up to 64 Hz was possible by the magnetometer and the whistlers were found at all local times within the ionosphere. The majority of the signals were detected when VEX was at $\sim$250 km, approximately 3% of the time at this altitude. The Poynting flux calculations were made for every signal detected and analyzed statistically to demonstrate that these waves have a source below the ionosphere.

This work has been led by Pr. C. T. Russell, Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, USA.

doi : https://meetingorganizer.copernicus.org/EPSC-DPS2019/EPSC-DPS2019-77-1.pdf

**(J. P. Pabari)**

**Impact of Surface Albedo on Martian Photochemistry**

Solar energy is the primary driving force behind a planets climate system, and surface albedo plays a key role in determining the energy budget of the planet. Coupling the Snow, Ice, and Aerosol Radiation (SNICAR) with the Laboratoire de Mtorologie Dynamique (LMD) Mars General Circulation Model (MGCM) to create a new coupled model leads to an approximately 4% drop in the net $CO_2$ ice deposition on Mars. Newly simulated surface albedo affects the concentration of gaseous species in the Martian atmosphere (condensation-sublimation cycle). The new set-up also impacts the solar energy available in the atmosphere. These two effects together lead to subsequent and significant changes in other chemical species in the Martian atmosphere. Compared with results of the MGCM model alone, in the new coupled model $CO_2$ (gas) and $O_3$ show a drop of about 1.17% and 8.59% in their respective concentrations, while $H_2O$ (vapor) and CO show an increase of about 13.63% and 0.56% in their respective concentrations. Among trace species, OH shows a maximum increase of about 29.44%, while the maximum drop of 11.5% is observed in the O concentration. Photochemically neutral species such as Ar and $N_2$ remain unaffected by the albedo changes.

doi : https://doi.org/10.26464/epp2020025

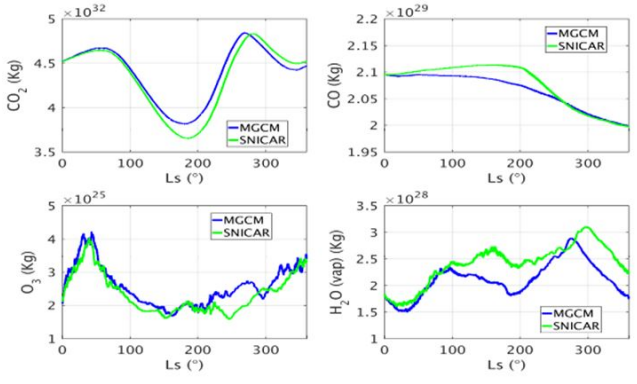


Figure 9: Global average plots of concentration of major species for one Martian year, using MGCM simulations (blue line) and S- MGCM simulations (green line)

**(D. Singh)**

**Development of experimental setup for ice-albedo studies on Mars**

Incoming solar energy and planetary albedo are two major factors that determine the energy budget of the planet which in turn impacts various physical processes on the planet. Added to this, the presence of dust in Marss climate system significantly impacts the planetary albedo. One of these aspects is the settling of airborne dust that affects the albedo and emissivity of the surface ice, thereby affecting the $CO_2$ and water cycles on Mars. It has been proposed to investigate the nature of these albedo feedbacks through laboratory studies under simulated Martian environment which can help us to better understand the processes/mechanisms related to polar ice chemistry. The basic idea is to derive optical constants of $CO_2$ and $H_2O$ ice through reflectance spectroscopy measurements in UV-VIS-NIR wavelength range on analogous soil under simulated Martian conditions. The optical constants thus derived would be utilized to explore the Martian polar ice chemistry which can significantly improve our understanding of the distribution of volatiles in the Mars Polar Regions. A Mars Environmental Simulation Chamber (MEC) is being custom-developed for carrying out these experiments. The design, fabrication, and assembly of MEC has been completed. The central cylinder has an internal diameter of 352 mm and a height of 330 mm. The chamber is provided with ports of various sizes to facilitate connection of vacuum and instrumentation feedthroughs. The integrity and performance of the chamber is currently being evaluated. Design of thermal plate along with sample holder is underway. For temperature control, Liquid Nitrogen ($LN_2$) in combination with cartridge heaters would be used. Terrestrial analog for Martian dust, such as Palagonite or JSC-Mars-1, would be used to simulate the effect of dust. In parallel, a fiber-based spectrometer (visible range) has been set up, and its response has been characterized. Set up for the integration of the spectrometer to the fabricated chamber is also being currently worked out in parallel. Next, a UV and NIR spectrometer with a light source would be integrated to obtain the reflectance spectra of the samples under simulated Martian environment as a function of various parameters.

**(D. Singh, Janmejay Kumar, P. K. S Reddy, M. Bhatt, K. Durga Prasad, V. Sheel, S. A. Haider)**

**An introduction to subsurface detections by SHAllow RADar (SHARAD) on MARS**

In this work, we have portrayed a brief overview of the concept and operation of the SHAllow RADar (SHARAD) sounding radar onboard MRO spacecraft the instrument is a powerful tool to analyze and understand the Mars geology, stratigraphy, and geographical evolution. We have discussed the SHARAD data analysis, graphical representation, and a plausible approach to determine the dielectric properties of the subsurface material. The analysis suggests that the subsurface reflections are the impression of dielectric properties of the subsurface material, and the respective dielectric permittivity may be obtained using the sounding radar observations of the subsurface reflectivity. The specs of SHARAD instrument make it appropriate to refine the stratigraphy for the first km beneath the top surface deposit. In essence, this instrument complements its companion instrument MARSIS, and both together are capable of providing unique insight about the Martian evolution, and planetary exploration. SHARAD has demonstrated its significance by discovering the ice layers around polar caps and in the northern and southern mid-latitude regions on Mars. Based on the present understanding of the orbiter radars, multifrequency operation of the instrument may be of significant means to complement the high penetration with better resolution in forthcoming projects such sounding radars are capable of probing the icy moons of Jupiter/ Saturn and the cometary atmosphere.

doi : https://www.tifr.res.in/~ipa1970/news/2020/PN_JanMar2020.pdf

**(S. K. Mishra and R. R. Bharti)**

**Superior Photo-thermionic electron Emission from Illuminated Phosphorene Surface**

Though the research on the layered black phosphorus initiated more than a century ago, exfoliation of phosphorene, an atomically thin two-dimensional (2D) material, from its layered bulk counterpart is experimentally achieved only recently. Since the first demonstrations, it is being considered a unique addition to the list of emerging 2D materials with a multitude of potential applications in nano-electronics and nano-photonics. While graphene, a planar honeycomb all-carbon 2D structure, has pertinence that relies on its exceptional properties such as high carrier mobility and high thermal conductivity, the absence of bandgap and low on-off ratios set limits on its performance. In contrast, phosphorene with both sufficiently large bandgap and high carrier mobility is an ideal candidate for wide-ranging optoelectronic applications and a new functional component for heterostructure synthesis. In this work, for the first time, the potential of black phosphorene as an efficient thermionic emitter has been demonstrated; it is also emphasized that its performance can be further enhanced through photon irradiation. We have manifested density functional theory (DFT) based energy structure and tight-binding (TB) model-based dispersion relation to address the coexisting and complementing thermionic and photo-thermionic emission from illuminated phosphorene structures. The cumulative emission flux is observed to be sensitive to the parametric tuning of the incident radiation and material specifications. Based on the parametric analysis, the photo-thermionic flux is noticed to strongly dominate over its coexisting counterpart thermionic emission flux, at lower surface temperature, and incident wavelength. Anisotropy in phosphorene structure plays an important role in enhancing the flux. The approach which is valid over a much wider range of parameters is successfully tested against recently performed experiments. The results open up a new possibility for the application of phosphorene based thermionic and photo-thermionic energy converters.

doi : https://doi.org/10.1038/s41598-019-44823-x

**(S. K. Mishra)**

**Chemisorption: A new route for formation of molecules in the astronomical environment**

Molecules are found in a broad range of astronomical environments, ranging from star-forming regions to the outer envelopes of carbon stars, and from objects in our own solar system (e.g., comets, asteroid) to distant metal-poor dust-poor galaxies. These molecules can be formed in both the gas phase and on the surfaces of interstellar dust grains, which are believed to be composed of silicates and carbonaceous material. Current astrochemical models include gas-phase chemical reactions in the temperature range between 10-800 K. However, reactions on dust surfaces commonly considered up to 200 K via physisorption in which ice mantles are formed. At higher grain temperatures, ice mantles desorb back into the gas, and the surfaces of dust grains become bare. Even at high temperatures, chemistry can occur on the bare dust grains via chemisorption due to the formation of strong chemical bonds between adsorbates and the bare grains. Recently, we studied the formation of molecules via chemisorption using several simple assumptions. We found that the importance of chemisorption is considerably dependent on the efficiency of adsorption. Models having the lowest adsorption barrier show maximum abundances of chemisorbed species. Species such as CO, which are very efficiently formed in the gas phase at almost all temperatures (10 to 400 K), will not be strongly impacted by the existence of chemisorbed species. However, chemisorbed CO can achieve a reasonably high abundance of $10^{-6}$ (compared to total hydrogen). Species such as $C_2H_2$ and $NH_3$, which are less efficiently formed compared with CO in the gas phase, may show a change in their gas-phase abundance due to chemisorption. Several examples of this class of species can also show reasonably high abundances on grain surfaces due to chemisorption when the adsorption barrier is low. Abundance of all classes of molecules goes down significantly with the decrease in adsorption efficiency.

doi : https://doi.org/10.3847/1538-4365/ab6599

**(K. Acharyya)**

## Remote Sensing and Data Analysis

**Luminescence dating of Quaternary alluvial successions, Sellicks Creek, South Mount Lofty Ranges, southern Australia**

Quaternary alluvial and colluvial sediments infill major river valleys and form alluvial fans and colluvium-filled bedrock depressions on the range fronts and within the Mount Lofty Ranges of southern Australia. A complex association of alluvial successions occurs in the Sellicks Creek drainage basin, as revealed from lithostratigraphy, physical landscape setting and optically stimulated luminescence (OSL) ages. Correlation of OSL ages with the Marine Oxygen Isotope record reveals that the alluvial successions represent multiple episodes of alluvial sedimentation since the penultimate glaciation (Marine Isotope Stage 6; MIS 6). The successions include a penultimate glacial maximum alluvium (Taringa Formation; 160 $\pm$ 15 ka; MIS 6), an unnamed alluvial succession (42 $\pm$ 3.2 ka; MIS 3), a late last glacial colluvial succession within bedrock depressions (ca 15 ka; MIS 2) and a late last glacial alluvium (ca 15 ka; MIS 2) in the lowest, distal portion of Sellicks Creek. In addition, the Waldeila Formation, a Holocene alluvium (3.5 $\pm$ 0.3 ka; MIS 1), and sediments deposited during a phase of Post-European Settlement Aggradation (PESA) are also identified. Neotectonic uplift locally enhanced erosion and sedimentation, while differences in drainage basin sizes along the margin of the ranges have influenced the timing and delivery of sediment in downstream locations. Close to the Willunga Fault Scarp at Sellicks Creek, sediments resembling the Pooraka Formation have yielded a pooled mean OSL age of 83.9 $\pm$ 7 ka (MIS 5a) corroborating the previously identified extended time range for deposition of the formation. Elsewhere, within major river valleys, the Pooraka Formation was deposited during the last interglacial maximum (128118 ka; MIS 5e). In general, alluviation occurred during interglacial and interstadial pluvial events, while erosion predominated during drier glacial episodes. OSL dating of the alluvial successions highlights linkages between the terrestrial and marine environments in association with sea-level (base-level) and climatic perturbations.

This work is done in collaboration with B. Bourman and C. Murray Wallace from University of Adelaide, Adelaide, Australia, and University of Wollongong, Wollongong, Australia.

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**(D. Banerjee and D. K. Panda)**

**The Ramgarh Structure-the third confirmed impact crater in India**

The Ramgarh structure (rim-to-rim diameter ∼2.4 km, Fig. 10 a) in the Vindhyan Supergroup of sedimentary rocks (including sandstone, shale and minor limestone) of the Mesoproterozoic age in the west-central India, is Indias third confirmed asteroid impact crater (after Lonar and Dhala structure). This eroded structure is roughly rectangular in shape and resembles to the Barringer Crater, USA. The presence of central peak and its current crater diameter/depth ratio of ∼12 well corroborate the range (1020) of terrestrial complex asteroid impact craters. The mm-sized, iron-rich (FeO ∼50 wt.% in average), spherule-like particles, recovered from the alluvium inside the Ramgarh structure, have internal morphology similar to those of the accretionary lapilli described in known impact craters (Fig. 10b). A few non-in situ, mm-sized particles, recovered from the rim of the structure show the presence of coesite, one of the diagnostic indicators of shock metamorphism (Fig. 10c). A few fragments of iron-rich, CaAlsilicate glasses recovered from the soil inside the structure and outside of the western crater rim include the presence of dendritic magnetite with occasional inclusions of relict native iron. Our microprobe analyses confirm that these metallic irons contain high proportions of Co (∼3503000 ppm), Ni (∼2004000 ppm) and Cu (∼22007000 ppm) and possibly could be the relict component of a Cu-rich iron meteorite impactor. The composite field observation and relative enrichment of compatible and incompatible trace elements in the spherule-like substance as compared to target rocks suggest that hydrothermal activity played an important role in the evolution of the crater.

This work is done in collaboration with S. Misra, UKZN, South Africa, D. Upadhyay, IIT, Kharagpur, India and H. Newsom, UNM, USA

doi : https://doi.org/10.1007/s12040-020-1371-7

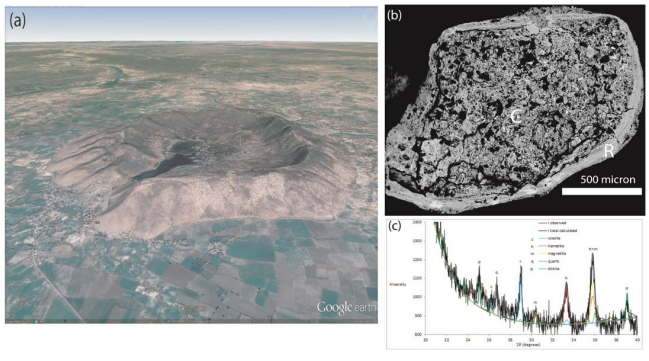


Figure 10: a. Oblique view of Ramgarh structure, India. b. Accretionary lapilli of Ramgarh Structure. C=Core; R=Rim. c. X-Ray Diffraction (XRD) of mm-sized impact-melt to show presence of coesite.

**(D. Ray)**

**High-resolution global maps of chemical elements on the Moon**

An in-depth understanding of the geological processes relevant for the formation and evolution of the Moon requires quantitative knowledge about the elemental composition of the lunar material at the high spatial resolution of lunar orbital near-infrared (NIR) hyperspectral images. However, the reflectance spectra obtained in the NIR wavelength range are an integrated response to the mineralogical composition and the presence of soil alteration processes, also known as space weathering effects. In order to determine the concentrations of the most important elements remotely by spectral analysis, the space weathering effects should be removed or minimized. Our method of estimating the concentrations of Fe, Ca, and Mg is based on a set of spectral parameters which are insensitive to the soil alteration processes. These parameters are used to construct a multivariate regression model, considering the global abundance data of the instruments Lunar Prospector Gamma Ray Spectrometer (LP GRS) and Kaguya GRS (KGRS) as ground truth. The GRS observations are at least two orders of magnitude lower in spatial resolution (tens of kilometers) in comparison to the hundreds of metres NIR spatial resolution. The proposed multivariate regression model combines the advantages of previous approaches which were based on Clementine global multispectral image data. It provides elemental abundance maps that are not perceivably affected by topography and maturity. For example, the rays of the crater Tycho, which consist of fresh (immature) material ejected during the crater-forming impact and has a composition similar to the surrounding surface, are hardly visible in the Fe, Mg and Ca abundance maps in Fig. 11.

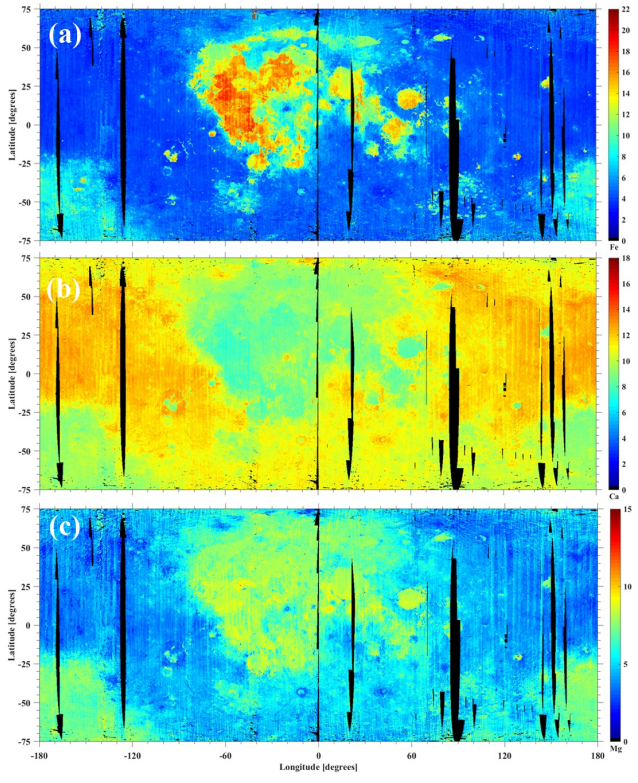


Figure 11: M3-derived global elemental maps using LP GRS elemental abundance data as reference. (a) Fe, (b) Ca, and (c) Mg.

In the maps, differences in composition between maria and highlands and also between different mare regions are clearly apparent. The algorithm will be further validated using data acquired by the Chandrayaan-2 orbiter. With the planned future missions for lunar and asteroid exploration, the newly developed methodology for elemental

abundance estimation based on NIR spectroscopy holds importance for the understanding of the formation and evolution of planets, and for the exploration and utilization of space resources.

This work has been done in collaboration with Prof. C. Wöhler, TU Dortmund, Germany.

doi : https://doi.org/10.1051/0004-6361/201935773

**(M. Bhatt)**

**Detection of excessively strong 3-$\mu$m absorption near the lunar highland crater Dufay**

Based on the analysis of Moon Mineralogy Mapper (M3) on-board Chandrayaan-1 we report a strong localized positive 3-$\mu$m band depth anomaly centered at 170.5°E and 8°N and associated with a bright structure of about 30x60 $km^2$ size. This unique structure does not have any perceivable topographic expression and situated between craters Dufay and Dufay X. This bright feature is the only localized positive 3-$\mu$m band depth anomaly of this kind which we found on the Moon after a rigorous search of the M3 derived global 3-$\mu$m band depth data set. This anomaly is characterized by an excess in 3-$\mu$m band depth of about 30% at midday relative to the surrounding highland surface. However it is by far not the brightest surface area in the farside highlands. Highland material that is similarly bright does not show positive 3-$\mu$m band depth anomalies. Our observations indicate that the lunar surface near the equator can accumulate OH/$H_2O$ in higher concentrations than in the illuminated polar highlands despite the high equatorial midday temperatures exceeding 380K. The spectral behaviour of this bright feature indicates a low soil maturity and a typical feldspathic highland composition. We do not observe any compositional differences between the reported bright structure and surroundings. Based on the available data, we suggest that the pronounced 3-$\mu$m band at midday exhibited is not due to its high albedo and low maturity alone. A possible explanation to the observations is a recent low-speed infall of a thin layer of OH/$H_2O$-rich meteoritic or cometary material, where the spectrally observed OH/$H_2O$ is assumed to be bounded in states of relatively high activation energy. We recommend targeted photometric and spectral observations of the structure with new dedicated spacecraft instrumentation in order to gain a more detailed understanding of the physical processes leading to the accumulation of OH/$H_2O$ in the lunar regolith surface.

This work has been led by Prof. C. Wöhler, TU Dortmund, Germany.

doi : https://doi.org/10.1051/0004-6361/201935927

**(M. Bhatt and A. Bhardwaj)**

**Potassium and Thorium Abundances at the South Pole-Aitken Basin Obtained by the Kaguya Gamma-Ray Spectrometer**

Incompatible elements such as K and Th are important to investigate the lunar mantle and crust since they remain as liquid until the final stage of crystallization. In this study, detailed K and Th distribution maps of the South Pole-Aitken (SPA) basin have been constructed for the first time from the Kaguya gamma-ray spectrometer (KGRS) data sets. This data-sets have been acquired during SELENE (Kaguya) low-altitude observations at 50 km with a 100-$km^2$ resolution for the compositional and evolutional studies. The K and Th distribution maps are compared with those obtained by KGRS high-altitude observation and Lunar Prospector GRS high- and low-altitude observations. The use of KGRS low-altitude data sets with high energy resolution enable to obtain unambiguous counts of individual gamma-ray lines, leading precise elemental maps of K and Th in comparison to previous studies. The newly derived maps implies the large SPA forming impact event led to ejection of K and Th rich materials, enhancing K and Th at SPA region. The SPA impact also caused convection of K and Th rich liquid layer toward the lunar nearside, resulting a depletion of these elements beneath SPA region.

This work has been led by Dr. M. Naito, School of Advanced Science and Engineering, Waseda University, Tokyo, Japan.

doi : https://doi.org/10.1029/2019JE005935

**(M. Bhatt)**

**Prospective $^3$He-rich landing sites on the Moon**

The $^3$He content in returned lunar samples was found to be higher with increasing soil maturity degree and $TiO_2$ content. The correlation coefficient between $^3$He content in nine measured Apollo soils and the $TiO_2$ content, solar wind flux, and maturity parameter was 0.944. We therefore constructed global $^3$He map using $TiO_2$ abundance data derived from the Moon Mineralogy Mapper ($M^3$) in combination with maps of the optical maturity (OMAT) parameter obtained using Clementine UV/VIS multispectral image data. The OMAT parameter quantifies the optical maturity of lunar soils, where large OMAT values correspond to immature material and vice versa. Detailed studies ($^3$He, $TiO_2$, FeO content, slope maps) of several regions with highest predicted $^3$He content such as the craters Grimaldi and Riccioli, Mare Moscoviense, the southern-western part of Oceanus Procellarum, the northern-western part of Mare Tranquillitatis, and the northern-eastern part of Mare Fecundidatis were presented. These regions are located on flat mare surfaces and have a high $TiO_2$ content. The studied regions, especially craters Grimaldi and Riccioli, were selected as candidate landing sites for missions aimed at extracting $^3$He from the lunar regolith.

This work has been led by Dr. K. J. Kim, Korea Institute of Geoscience and Mineral Resources, South Korea.

doi : https://doi.org/10.1016/j.pss.2019.07.001

**(M. Bhatt)**

**Planetary Remote Sensing Laboratory: a New Facility**

Remotely acquired spectral reflectance measurements in the UVVISNIR region provide mineralogical information, since, minerals exhibit different spectral response as a function of their composition and crystal structure. Most planetary missions carry reflectance spectrometers onboard for deciphering mineralogical composition

of the planetary surfaces. Various ongoing & recently concluded missions such as Chandrayaan-2 (2019), Chandrayaan-1 (2008), Dawn (2007), MRO (2005), and Rosetta (2004) carry either one or a suite of reflectance spectrometers. Therefore, a wealth of data already exists and significantly more will be available in the near future. Interpretation of these distant signals is a complicated task due to lack of ground truth and numerous parameters that influence reflectance values. Therefore, it is imperative to carry out intensive laboratory spectral reflectance studies of extraterrestrial samples and analogues under simulated conditions. We have developed a laboratory dedicated for carrying out reflectance spectroscopy of planetary materials (meteorites & returned samples) and their analogues in the spectral range (350-2500 nm) under simulated conditions. Primarily, the laboratory constitutes of an off-the-shelf ASD Fieldspec spectroradiometer and two custom built instruments a) A spectro-goniometer and b) A Planetary Environmental Chamber

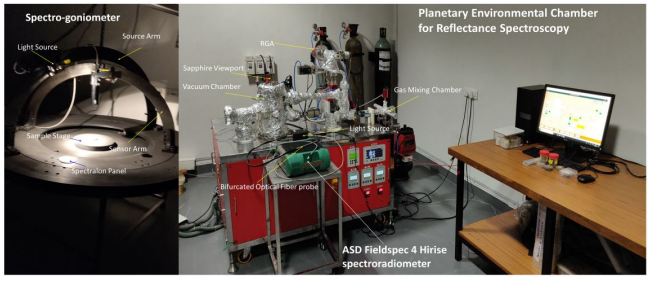


Figure 12: The Planetary Remote Sensing Laboratory showing the spectro-goniometer (left) and the planetary environmental chamber with ASD Fieldspec spectroradiometer (right)

**(N. Srivastava)**

### Detection of skylights in the Hebrus Valles region of Mars

The Martian caves have revived interest in the field of speleology because they are the potential destinations for future human residences and astrobiological research.

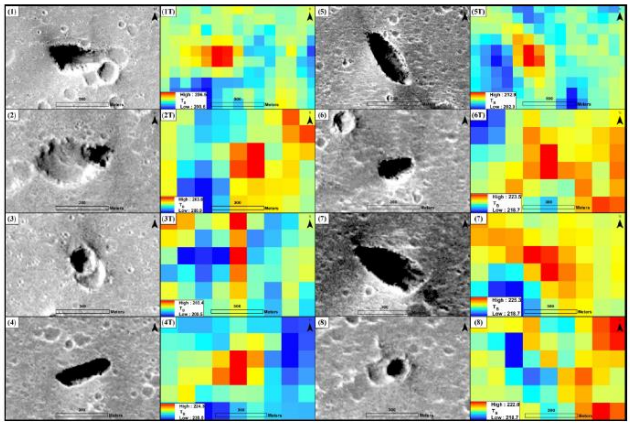

Figure 13: CTX images showing skylight candidates in Hebrus Valles region (SK 1-8), with corresponding IRPBT data (right side). All these, except Skylight 8 exhibit hotter appearance at night time compared to the surroundings. Skylights 1, 3, 5-7 are newly discovered ones in this study.

Thus, skylights are the doors to access subsurface caves. Signature of life is probable in a sub-surface cave on Mars as it can protect life from the harsh environment of the surface. In a cave, there may be an abundance of minerals, fluids and other key resources. Hence, locating skylights is essential and crucial for formulating future plans for robotic/human exploration of the Red Planet Mars. In this study we have used remote sensing data from MRO (Mars Reconnaissance Orbiter; NASA) and Mars Odyssey (NASA) to identify skylights in the Hebrus Valles region of Mars, centered at (20° 40' 31.9" N, 126° 23' 56.2" E), on the basis of their morphology, morphometry and thermal behavior. A total of five new skylights (SK 1, 3, 5-7) have been discovered in the region.

doi : https://www.hou.usra.edu/meetings/lpsc2018/pdf/1218.pdf

**(N. Srivastava)**

### Chandrayaan 2 landing site in the southern high latitudes of the Moon

ISROs Chandrayaan-2 Vikram lander was scheduled to land near the southern polar region within an area between 70 to 72° S and 22 to 24° E. We have carried out detailed geological characterization of the landing region to provide a contextual framework for in situ investigations at the proposed landing region.

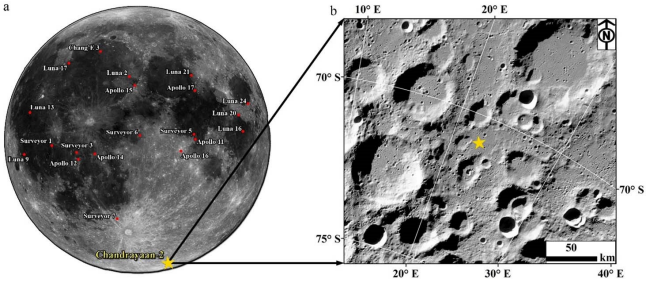


Figure 14: (a) Lunar Reconnaissance Orbiter Wide Angle Camera (LROC WAC) (resolution 100 m/pixel) mosaic of the near side of Moon; Star symbol: proposed location of Chandrayaan-2 landing site; Circle symbol: locations of previous landing missions (b) LROC WAC polar stereographic mosaic of proposed landing region (star symbol).

Study reveals that the landing region is consistent with surface slope values less than 15° and the crater size frequency distribution method suggests that the geological age of the landing region is ∼3.7 billion years. The craters surrounding the landing region typically predates the landing region, which indicates that the ejecta from these craters may be mantled over the landing region. Furthermore, a large number of smaller (few km) to larger (few tens of km) impact craters surround the landing region. In addition, the oldest impact basin in the Solar System named South Pole Aitken (SPA) basin (diameter ∼2500 km) is situated quite close (∼350 km) to the landing region. So the possibility exists that deep crustal materials excavated during the formation of this large SPA basin might have redistributed materials in the landing region. The mineralogical investigation of the landing region reveals abundance of elements, like Fe: 4.2wt%, Mg: 5.4wt%, Ca: 10wt%, and Ti: 0.3wt%. Datasets acquired by the Imaging Infrared Spectrometer (IIRS) operating in the spectral range of ∼0.8-5.0 $\mu$m

for the first time, at the high spectral resolution of ∼20 nm, can give crucial insights into the contextual relationship between the materials excavated from the SPA basin impact and their emplacement in the landing region. Altogether, it is evident that the various sizes of impact craters surrounding the landing site could lead to mixing of lunar highland and crater/basin ejecta materials, resulting in hybridisation of highland regolith.

This work has been done in collaboration with Prof. C. Wöhler, TU Dortmund, Germany.

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**(R. K. Sinha, Vijayan S., M. Bhatt, Harish N., Nandita Kumari, N. Srivastava, I. Varatharajan, D. Ray and A. Bhardwaj)**

## Meteorite, Analogue and Laboratory Studies

### Merrilite Rim around the Phyllosilicate clast in Mukundpura Carbonecous Chondrite (CM2)

The CM2 type of meteorites have been investigated for understanding the asteroidal aqueous alteration processes. The alteration processes induce formation of secondary and hydrous minerals like phyllosilicates, calcites, poorly charachterized phases and phosphates. The occurrences of phosphate minerals have been generally postulated due to fluid assisted metasomatism on the parent body.In this study, we discuss the mineralogy, formation process of phosphate mineral phases, uniquely occurred within a phyllosilicate clast, with an aim to understand aqueous alteration history in Mukundpura CM2.

BSE and X-ray images have been studied using JEOL IT300 scanning electron microscope with an OXFORD EDS operated at 20 keV, 500pA. The elemental concentration has been measured using Cameca SX 100 electron microprobe with operation biasing voltage of 15 kV, 15nA with 2 $\mu$m beam diameter. From the BSE and chemical composition analysis it has been observed that all the chondrule and the matrix of the meteorite are highly altered except a few isolated chondrule appears to be survived as a relict clast and fayalitic in composition. Interestingly, one of the studied sections hosts an altered chondrule ∼100 $\mu$m size and is surrounded by CaP rich fine-grained rim. The rim width also varies from 4 to 10 $\mu$m in size. From the X-ray mapping and line scan of composition, it appears that the Ca-P layer is not homogeneous in nature. The EPMA elemental analysis shows CaO 50-42 % & P2O5 30-25.6%. with Na2O 1.8 to 3.2 %, MgO 1.5-4.4%, FeO 4-7 %. The phyllosilicates and calcite are common near the fracture zone of the rim. The chondrule at the interior is altered and compositionally akin to Cr- rich phyllosilicates. The EPMA analysis also shows that phyllosilicates in the matrix are phosphorus rich (upto 7.5 % of $P_2O_5$), while the PCP are relatively depleted in $P_2O_5$ (0.1-0.2 %). The calcite is also occasionally found enriched with phosphorus ($P_2O_5$ 0.4-1.1 %). Based on SEM study, it appears that Mukundpura is depleted in CAI (Calcium-Aluminium Inclusion), clast-rich CM2 with a highly altered matrix rich chondrite. The occurrences of phosphorus phases in terms of phosphate at reaction rim clearly suggests the migration of P and Ca from some Fe-Ni and CAI bearing phases. The X-ray maping and EPMA analysis show the presence of Na, Mg, Fe in phosphate, whereas Cl and F are apparently absent. Based on the chemical analysis, the rim formation the phosphate mineral resembles merrilite in composition. The phosphate mineral is secondary product which can be formed due to interaction of fluid which led to migration of elements and formation, thereafter. Apart from this the phosphate mineral also can be formed by fluid assisted metamorphism. In our studied sections of the Mukundpura the concentric inward growth texture of hydrous clast can be also considered as an additional evidence for migration of fluids or testifies substantial aqueous activities. Based on chemical anlysis and textural characters, it can be postulated that during the alteration process Ca, P, Na migrated to form the fine-grained Ca-P rich rim. The Ca-P mineral phases are associated with $CaCO_3$ grains outside the Ca-P rim. It is to be noted that the concentration of P and S increased in the phyllosilicates which may be due to the fluid interaction processes of Fe-Ni-S-P with the matrix Conclusion: Our study suggests that Mukundpura experienced complex aqueous alteration processes. The presence of phosphate (Merrilite) mineral is formed due to the low temperature alteration processes.

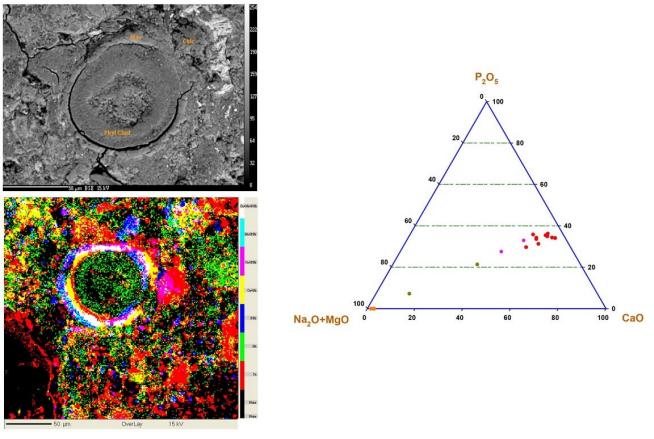


Figure 15: Merillite rim around a Phyllosilicate clast. (a) BSE picture of the merillite rim where Mer-Merillite, Calc - calcite and Phyl- phyllosilicate. (b) X-ray overly image of Ca, P and Na X-ray image. (c) ternary plot of CaO, $P_2O_5$ and $N_2O$+MgO.

doi : https://doi.org/10.1111/maps.13346

**(D. K. Panda, D. Ray and A. D. Shukla)**

### Shock-Thermal history of Agoudal (IIAB) iron: A new find in Morocco

The Agoudal IIAB iron meteorite exhibits only kamacite grains (∼6 mm across) without any taenite. The kamacite is homogeneously enriched with numerous rhabdite inclusions of different size, shape, and composition. In some kamacite domains, this appears frosty due to micron-scale rhabdite inclusions (∼5 to 100 $\mu$m) of moderate to high Ni content (∼26 to 40 wt%). In addition, all the kamacite grains in matrix are marked with a prominent linear crack formed during an atmospheric break-up event and subsequently oxidized. This feature, also defined by trails of lowest Ni-bearing (mean Ni: 23 wt%) mm scale rhabdite plates (fractured and oxidized) could be a trace of a pre-existing $\gamma\alpha$ interface. Agoudal experienced a very slow rate of primary cooling ∼4 $^{\circ}$C $Ma^{-1}$ estimated from the binary

plots of true rhabdite width against corresponding Ni wt% and the computed cooling rate curves after Randich and Goldstein (1978). Chemically, Agoudal iron (Ga: 54 ppm; Ge: 140 ppm; Ir: 0.03 ppm) resembles the Ainsworth iron, the coarsest octahedrite of the IIAB iron group. Agoudal contains multiple sets of Neumann bands that are formed in space and time at different scales and densities due to numerous impacts with shock magnitude up to 130 kb. Signatures of recrystallization due to post-shock low temperature mild reheating are also locally present.

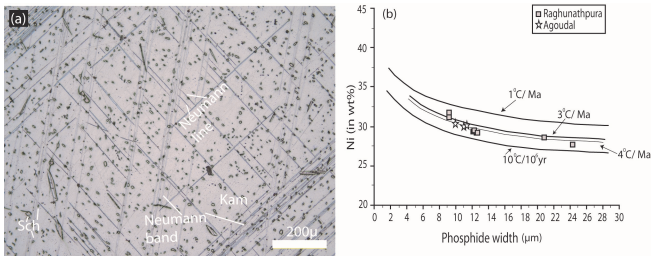


Figure 16: Reflected light images showing unannealed orthogonal sets of Neumann lines in Agoudal iron. 2b. Phosphide bandwidth versus Ni content. The bold curves were derived from numerically simulated phosphide growth in kamacite.

doi : https://doi.org/10.1111/maps.13399

**(D. Ray)**

**Minor element zonation of refractory forsterite in Mukundpura chondrite: Implications for primitive aqueous alteration**

Mukundpura is a carbonaceous chondrite (CM2) recently fell in Rajasthan, India (June 6, 2017). A typical fine-grained, clast-dominant matrix contains a few isolated forsterite and FeO-rich olivine grains. In this study, forsterite-rich olivines were investigated using colour cathodoluminescence (CL) and Raman spectroscopy in order to explain the primitive stages of asteroidal aqueous alteration.

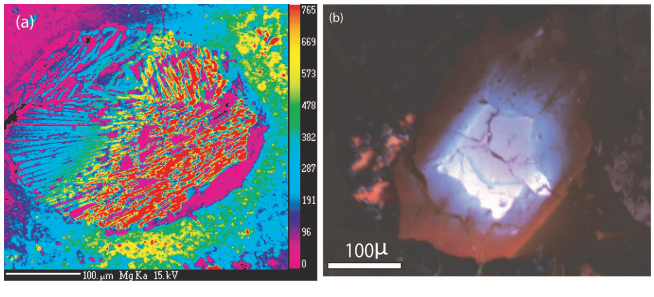


Figure 17: Mg K$\alpha$ X-ray image of Barred olivine chondrule and (b) Color CL image of refractory forsterite in Mukundpura CM2

Isolated forsterite ($Fo_{99}$) in Mukundpura emits bright CL of varying colour and shows CL zonation in different patterns accounting the structural defects and chemical inhomogeneity. Blue luminescence (also distinguished by enriched CaO and $TiO_2$) is common in cores of the relict forsterite attributing refractory (high temperature of formation) nature of the olivine. Electron Probe Microanalyzer (EPMA) line scan across the CL-active forsterite grains shows minor elements zonation especially for activator elements and thus provide a correlation of colour of the emitted luminescence with diffusible ions. The red CL zonation (also characterised by enriched FeO, $Cr_2O_3$ and MnO content) is common along the majority of forsterite rims suggesting aqueous activity in the parent asteroid. The strongest doublet Raman peaks corresponding to 821 $cm^{-1}$ and 854 $cm^{-1}$ are due to $SiO_4$ tetrahedral vibrational modes and other peaks are often related to infer pure crystalline state of the forsterite. Thus, a combination of CL imaging and Raman spectroscopy is useful to explain the chemical-structural properties of luminescent pure forsterite and also help in understanding the aqueous alteration of CM chondrite.

doi : https://www.hou.usra.edu/meetings/lpsc2019/pdf/1603.pdf

**(S. Baliyan and D. Ray)**

## Development of Payloads for Planetary Mission

**Supra Thermal & Energetic Particle Spectrometer (STEPS) - Subsystem of ASPEX payload**

Aditya Solar wind Particle EXperiment (ASPEX) is one of the seven scientific experiments onboard the Aditya - L1 mission (the forthcoming Indian solar mission), to be placed in a halo orbit around the L1 Lagrangian point of the Sun-Earth system, at a distance of 1.5 million km from the Earth. ASPEX will carry out the in-situ, multi-directional measurements of the slow and fast solar wind, supra-thermal particles and solar energetic particles in the energy range of 100 eV to 20 MeV/n with its two sub-systems namely Solar Wind Ion Spectrometer (SWIS) and Supra Thermal & Energetic Particle Spectrometer (STEPS). SWIS measures the angular and energy distribution of solar wind ions in the energy range of 100 eV to 20 keV and STEPS measures the energy spectrum of high energetic particles from six directions covering the energy range of 20 keV/n to 20 MeV/n. The scientific objective of the STEPS is to investigate the origin of the suprathermal particles and their relationship with the primary solar wind constituents. The STEPS subsystem has been configured into three packages: STEPS-1, STEPS-2A & STEPS-2B. STEPS-1 has four detector units for four different directional measurements (1) Sun Radial (SR), (2) Intermediate to Sun radial and Parker Spiral (IM), (3) Parker Spiral (PS) and (4) Northward direction (NP). STEPS-2A has one detector unit for Earthward (EP) directional measurements and front-end electronics for the STEPS-2B package, which has one detector unit for the southward (SP) directional measurements. Silicon Photomulitplier (SiPM) along with plastic scintillator is in use in the STEPS for the high-energy particle detection. SiPM is being qualified for space use. Total 21 sets of Scintillator+SiPM assembly have been screened as per the qualification plans. The plans include the burn-in, thermal cycling, thermo-vacuum test, radiation test, vibration test etc. Three assemblies have been subjected to the acceptance as well as qualification level vibration levels for the qualification. Functionality test for the pre and post vibration levels have been tested and verified. Figure 18 shows three assemblies in the STEPS-1 and STEPS-2A packages. All the PCB cards (total 14 nos.) for the flight model of the STEPS have been fully wired and functionally tested. Figure

19 shows the photographs of the STEPS-processing electronics card and DC-DC card for the powering of the STEPS. FM assembly of the STEPS-2A & STEPS-2B has been over. FM assembly of the STEPS-1 package and STEPS-processing electronics package will be carried out soon. Test & Evaluation (T&E) plans have been worked out. T&E tests will be started as soon as the FM assemblies of all packages are over.

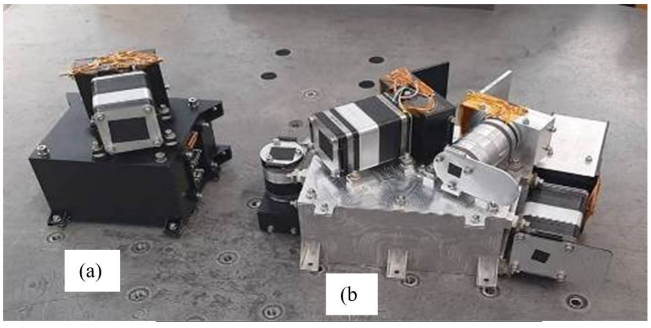


Figure 18: (a) STEPS-2A model & (b) STEPS-1 model

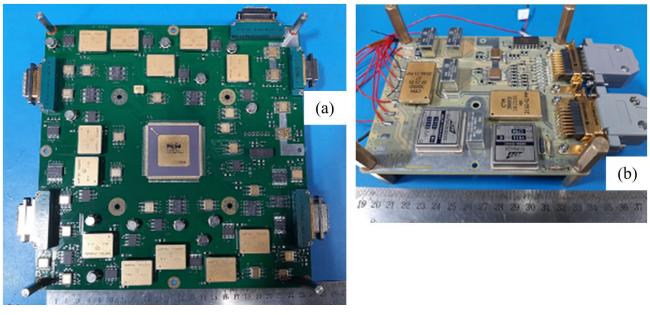


Figure 19: (a) STEPS-FPGA card, (b) STEPS-DC-DC power card

**(S. K. Goyal, M. Shanmugam, A. R. Patel, N. K. Tiwari, T. Ladiya, A. Sarada, S. V. Vadawale, P. Janardhan, D. Chakrabarty, A. Sarkar, A. Auknoor, P. Sharma, Sushil, Deepak and Team)**

**Energetic Ion Spectrometer (EIS) for Mars Orbiter Mission (MOM-2)**

Energetic particles of the solar and interplanetary origin continuously bombard the Martian ionosphere and can play an important role in the atmospheric loss processes at a shorter time scale. These particles can change the state of the Martian ionosphere significantly. In order to evaluate and quantify the changes in the Martian ionosphere due to the arrival of energetic particles generated close to the Sun during flare or due to the passage of interplanetary coronal mass ejection (ICME) and co-rotating interaction region (CIR), it is important to identify the arrival of these energetic particles at the Martian orbit relatively accurately. By measuring the alpha ($H^{++}$) - proton ($He^{++}$) ratio in the Solar Energetic Particles (SEP), the precise time of arrival of these particles at the Martian orbit will be known. Further, measurements of the proton and alpha fluxes at the Martian orbit will also help to understand the energetic particle environment around the Martian orbit. Keeping these objectives in mind, the Energetic Ion Spectrometer (EIS) is planned for future Indian Mars Orbiter Mission. The prime objective of the EIS is to make the in-situ measurements of the high-energy charged particles ($H^{+}$ and $He^{++}$) in the energy range of 20 keV/n to 40 MeV/n from the Martian orbit. EIS uses customized Si-PIN detectors in the $\Delta$E-E configuration mode for the energy measurement and identification of the $H^{+}$ and $He^{++}$ particles. Figure 20 shows the block schematic for the detectors configuration. EIS uses a stack of 20 $\mu$m thick and 1.5 mm thick Si-PIN detectors to cover the entire energy range. Third detector is placed behind the 1.5 mm Si-PIN detector to work in the flag mode. This detector and the Anti-Coincidence Shield (ACS) are designed using plastic scintillator and Silicon Photomultiplier (SiPM) readout.

Front End Electronics (FEE) for both the detectors consists of two independent chains of charge sensitive preamplifiers, shaping amplifiers and discriminators circuits. Figure 21 shows the PCB designed and tested for 1.5 mm thick Si-PIN detector. Both the detectors (20 $\mu$m thick and 1.5 mm thick) have been tested using $^{241}$Am radioactive sources. The energy threshold achieved for both the detectors is $<$ 20 keV, as required for the EIS having energy range of 20 keV to 40 MeV/n. Preliminary results acquired for 1.5 mm thick detector is shown in Figure 22.

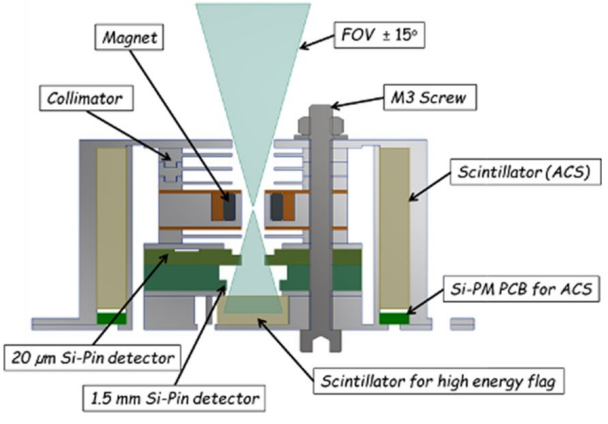


Figure 20: Block schematic showing the detectors' arrangements

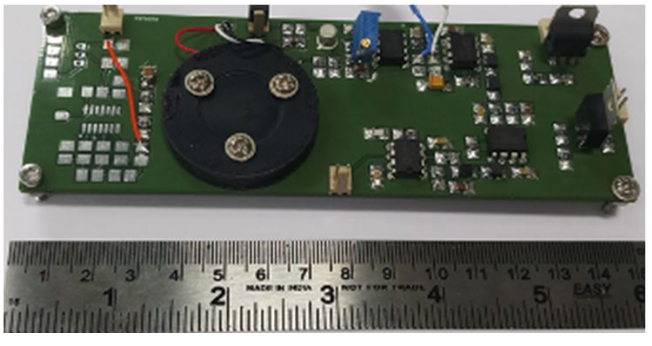

Figure 21: FEE PCB for 1.5 mm SiPIN detector

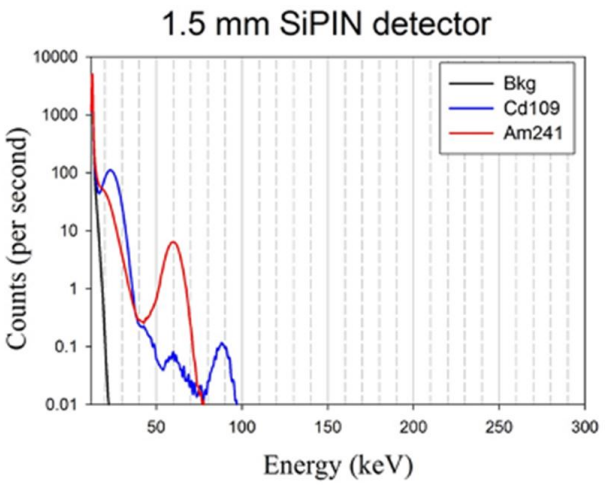


Figure 22: Preliminary result for 1.5 mm thick SiPIN detectors using $^{241}$Am and $^{109}$Cd radioactive sources.

**(S. K. Goyal, A. Auknoor, P. Sharma, A. Sarda, N. K. Tiwari, D. Chakrabarty and S. V. Vadawale)**

**Neutral & Ion Mass Spectrometer (NIMS)**

Neutral and ion mass spectrometer is being developed for in-situ measurements of neutral and ion species. The instrument has been selected to fly on nano-satellite mission to Venus. The proposed altitude of working the instrument is from ∼250 km to ∼80-100 km. The scientific objective of the instrument is to measure the composition, structure, variability and thermal state of the Venus atmosphere and its dynamics. The mass spectrometer will operate in the dual mode, separately for both neutrals and ions in the mass range of 2 to 200 m/q. The basic instrument consists of an ionizer, which converts neutral species into positive ions, quadruple filter for scanning of the charged particle as per their m/q ratio and CEM detector. Along with this, the instrument also consists of the onboard Vacuum pumps i.e. miniaturized turbo pump and miniaturized scroll pump to maintain the vacuum levels inside the mass spectrometer. The required control electronics for the pumps have been developed and tested. Figure 23 shows the test assembly for the operation of the vacuum pumps. The achieved vacuum level is $\sim 10^{-5}$ Torr in $<$5 minutes time. The required electronics for all three parts: Ionizer, quadrupole filter and detector current readout has been developed and tested with the in-house designed quadrupole mass analyzer. The engineering model has been designed and first preliminary result is shown in the Figure 24. Data in Figure 24 is acquired at the vacuum level of $<10^{-6}$ Torr level with 70 eV electron ionization energy. The tuning of the parameters along with mass, density calibration is going ON. The instrument is planned to be flown on the balloon platform using TIFR balloon facility, Hyderabad. Further plans include flying the instrument on PS4 platform for its functional verification and measurement of the Earths composition at around 500 km altitude.

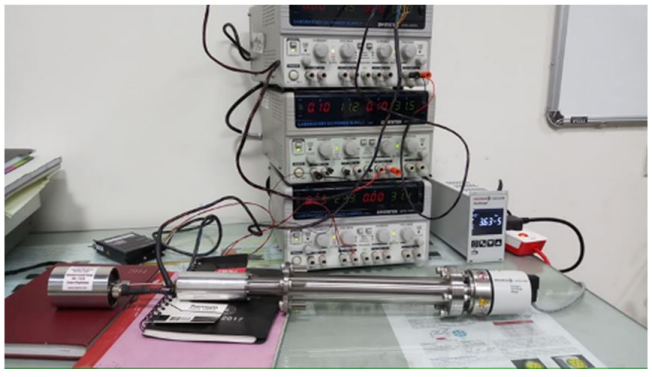

Figure 23: Quadrupole vacuum assembly for the testing of the scroll and Turbo pumps.

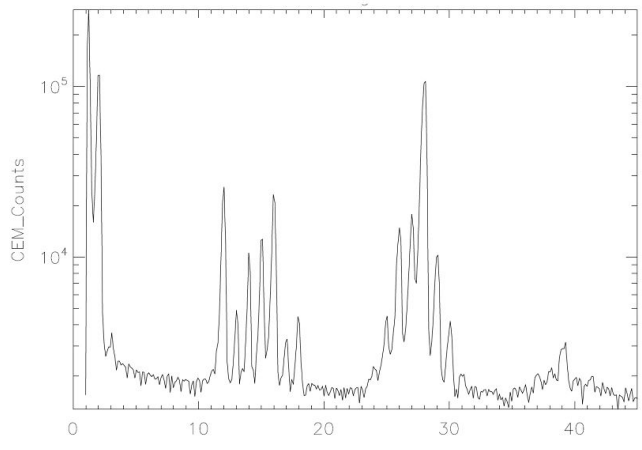


Figure 24: Plot shows the raw data for CEM_counts with m/q. Various peaks (major are: 12, 16 and 28) are observed, electron ionization energy is 70 eV.

**(S. K. Goyal, R. R. Mahajan, A. Auknoor, P. Sharma, J. Mehar, N. K. Upadhyay, V. Sheel, S. A. Haider and A. Bhardwaj)**

**Langmuir Probe for LPEX onboard MOM-2 - DVM Design and testing**

We have earlier reported the functional demonstration of front-end electronics (FE) of Langmuir probe (LP) of the LPEX (Langmuir Probe and Electric Field experiment) being developed for Indian Mars Orbiter Mission-2 (MOM-2). The design of FE has now been upgraded in terms of its measurement sensitivity, dynamic range and noise immunity etc. The other sub-systems of LP viz. miniaturized pre-amplifier, precision current and voltage monitoring, sweep and bias generation, isolation, filter design and signal processing have also now been developed and tested end-to-end to evaluate its performance. The electrometer was evolved over numerous design modifications and testing. The electrometer now has a capability of measuring currents in order of $10^{-10}$ A $10^{-4}$ A with an 8-stage automatic gain switching. Based on the detailed design study and evaluation, a guard plane and usage of triaxial connector has now

been accommodated during the PCB design and fabrication for better noise immunity and overcome parasite effects. The sweep bias electronics has also been designed and integrated which has a provision of biasing from -10V - +10V to the sensor. The sweep dwell time and sweep ranges can be programmed to suitable limits as per the orbit requirements. In addition to this, back-end processing hardware using an 8-bit microcontroller and quick look GUI software have also been designed for end-to-end testing of the Design verification Model of LP. The performance of the integrated Langmuir probe system has been evaluated using a series of experiments.

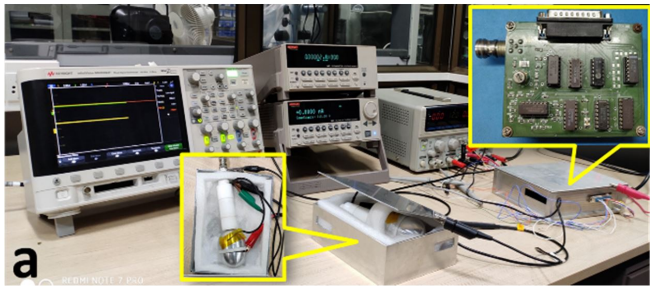


Figure 25: End-to-End testing of LP Design Verification Model

**(K. Durga Prasad, Chandan Kumar, Sanjeev Mishra, P. Kalyan S. Reddy, Janmejay Kumar, Varun Sheel, S.A. Haider and A. Bhardwaj)**

**Design and evaluation of front-end and filter blocks of Electric field instrument of LPEX onboard MOM-2**

Electric Field (EF) instrument is part of the LPEX payload that is being developed for ISROs Mars Orbiter Mission-2. The lab verification model of the EF front-end reported earlier has been thoroughly evaluated in terms of its performance and implementation to arrive at an optimum configuration for the EF card. The EF part consists of three major blocks- Preamplifiers, Signal Conditioning and Analog Filtering. Apart from this, bias voltage generation for sensors and guards, calibration signal generation for the sensors are also required. Several schemes have been evaluated by simulating various techniques followed by their implementation using general purpose PCBs. After detailed evaluation, two different layouts were prepared, and PCBs fabricated. Rigorous testing of the populated cards was carried out and their key performance parameters were evaluated. During evaluation, certain issues such as stray and parasitic effects were observed. Following which a detailed debugging of the card was carried out and the resulting modifications were included in the next iteration of the design. After few iterations, the current version of the FE card consisting of preamp, signal conditioning, analog filtering and biasing was realised, implemented and tested. The present design has a voltage sensitivity of $\sim$250 $\mu$V at analog level which we expect to improve further. In addition to FE, filter blocks were also implemented. The implemented filter block consisted of three channels- A Low Pass Filter with $F_c$=300 Hz (EFLPF), Band Pass filters of range 100 Hz-1.2 kHz (EFMF) and 1 kHz -5 kHz (EFHF). The test results show considerable improvement in filter response and further design modifications are being carried out to refine the filter response and increase the overall sensitivity of the EF card. Figure 26 shows a screen shot of testing of the current version of EF front-end. The figure also shows the response of two of the filters realised.

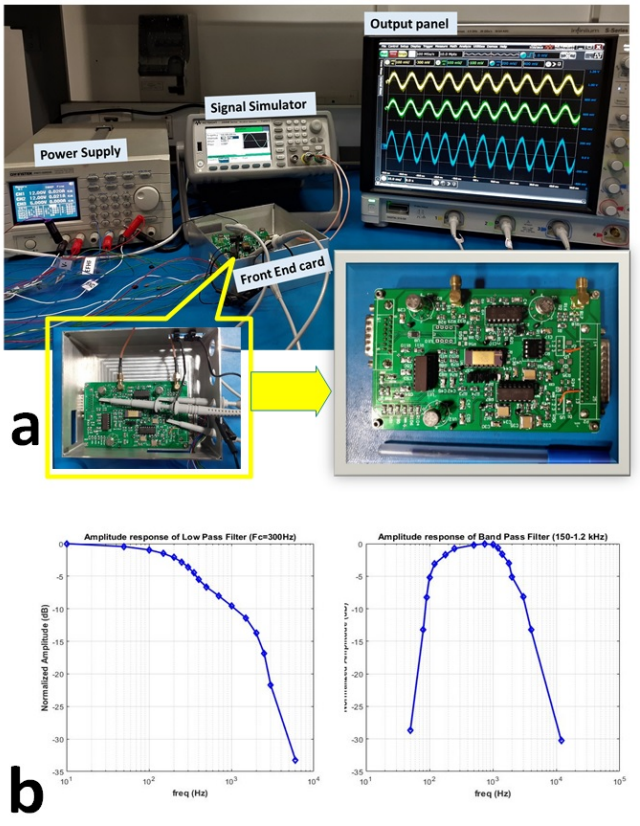


Figure 26: (a) Experimental Verification of Electric Field Electronics (b) Low Pass and Band Pass Filter responses

**(K. Durga Prasad, Chandan Kumar, Sanjeev Mishra, P. Kalyan S. Reddy, Janmejay Kumar, Varun Sheel, S.A. Haider and A. Bhardwaj)**

**Development of a Meteorology Suite for Future Planetary Balloon Missions**

Balloons provide a unique and long-term platform which can facilitate us to carry-out in-situ investigations in the middle atmospheres of planetary bodies (such as Venus, Titan, Enceladus etc.) which is a source of highly complex and dynamical processes. Balloon missions can be considered as prospective tool for in-situ exploration of these regimes which usually lie at altitudes between $\sim$40km 70 km. If we consider the case of Venus, 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. In an anticipation to study these aspects onboard future missions, a small instrument suite with imaging capability is being developed for in-situ investigation of local meteorological parameters - Temperature, Pressure, Ambient Light/Solar Radiation

and Wind velocities. The instrument is being built around a radiation hardened 8-bit micro-controller and would utilize miniaturized sensors for measurement of scientific parameters. All the sensors are mounted in such a fashion that they can have direct access to the ambient environment planned to be sampled. This suite can detect ambient temperatures in the range of -250$^{\circ}$C to 250$^{\circ}$C. The pressure sensor operates over the range of few mbar to $\sim$2 bar. The ambient light measurements can be carried out for various light intensities from 10 mLux to 10 KLux owing to its high dynamic range. The sensor selection, electronics design, and mechanical housing all were made keeping in mind the miniaturization aspect of the instrument. Presently a Bread Board Model of the isntrument is designed and integrated with sensors. The sensor calibration is currently underway and we plan to evaluate the performance of this instrument using an Earth-borne balloon platform. Figure 27 shows the bread board model of the meteorology suite under development and the set-up designed for pressure calibration.

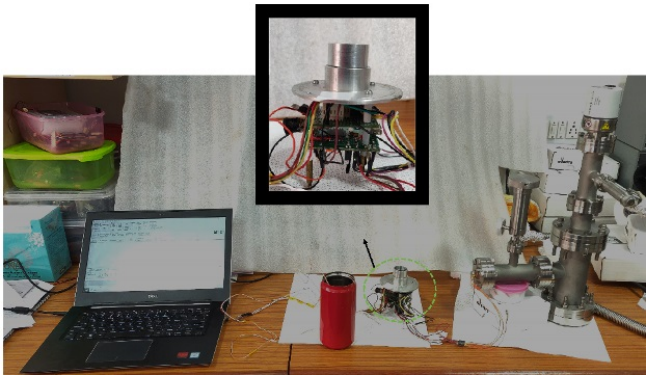

Figure 27: Breadboard Model of the developed MET Suite and Pressure Calibration Setup

**(K. Durga Prasad, Chandan Kumar, Sanjeev K. Mishra, P. Kalyan Reddy, Janmejay Kumar, Varun Sheel, S.A. Haider and A. Bhardwaj)**

**Laboratory evaluation of a dielectric probe for lunar water-ice detection**

The possibility of the presence of water ice deposits in the polar regions of the moon has drawn a lot of attention in the recent past and continues to be of great interest. Recent results suggest towards the existence of a significant amount of particle bound Water-ice mixed with regolith at the surface and subsurface, particularly towards high and polar latitude regions of the Moon. In-situ detection and quantification of this water-ice would be of significant interest not only to understand the presence distribution and transport of volatiles on lunar surface but it will also be an important aspect for future human exploration and in-situ resource utilization on the Moon. We have proposed to develop a water-ice prospecting device called Permittivity and Thermophysical Instrument for Moons Aquatic Scout (PRATHIMA) for lunar polar exploration in future. The instrument aims at in-situ investigation of water-ice in the lunar polar regions using simultaneous electrical and thermophysical investigations of the surface and subsurface. Laboratory work for demonstrating the proof of concept that dielectric / electric field measurements can be used to detect regolith bound water-ice has been initiated and details about some of our initial studies are provided here. A mole-shaped prototype dielectric/electric-field probe using Teflon tube and copper foil as radial transmitter (Tx) /receiver (Rx) electrodes has been custom-developed for concept evaluation. A software controlled external signal generator circuit connected to the Tx electrodes is used to launch an AC electric field wave of desired frequency into the medium (soil). The reflected EF wave from the soil with certain delay received from the Rx electrodes is further connected to an analog processing and data acquisition unit for deriving the electrical properties (dielectric permittivity) as a function of frequency. The measurements were also carried out using a table top network analyser system in parallel for validation purposes. Results from our preliminary experiments show a significant variation in the dielectric permittivity of the sample due to the presence of water/ice particularly at specific frequencies. The work is currently ongoing and a series of experiments are planned using various designs/configurations of the probe and electronics to establish the concept.

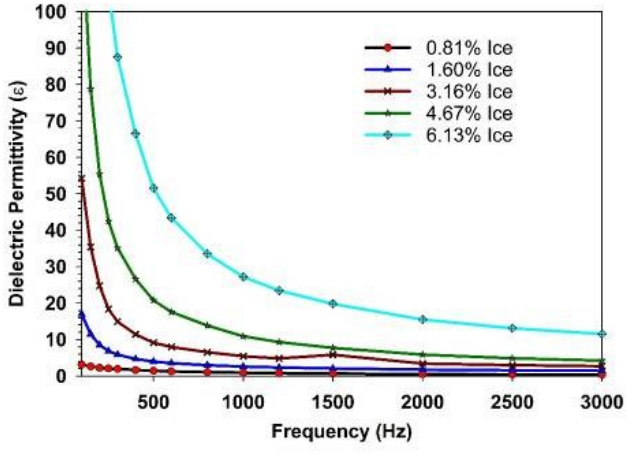


Figure 28: Experimental result for variation of dielectric permittivity for different concentration of ice mixed with soil

**(P. Nikitha, Sanjeev Kumar Mishra, K. Durga Prasad)**

**Solar X-ray Monitor on-board Chandrayaan-2: In-flight operations and performance**

Chandrayaan-2, India's second mission to moon, was launched into an earth-bound or-bit on 22 July, 2019 by GSLV MkIII-M1. After a series of orbit manoeuvres, the space-craft reached the lunar orbit and the orbiter-craft started its nominal operations in early September. Solar X-ray Monitor (XSM) is one of the scientific instruments on-board the Chandrayaan-2 orbiter, which is aimed to carry out X-ray spectroscopy of the sun. XSM had its initial power-on during the earth-bound phase to test the instrument operation as well as to asses its performance with the on-board calibration source. The instrument operated flawlessly and the measured spectral resolution at 5.9 keV was $\sim$175 eV, exactly matching the requirements as well as the ground calibration. XSM underwent multiple passages through the earth's radiation belts before reaching the nominal lunar orbit. Measurement of spectral resolution in the lunar orbit shows no degradation in performance after this radiation exposure. From 12 September, 2019, XSM began its nominal operations observing the

Sun. Since then, XSM has been almost continuously powered on with the exception of duration of orbit maneuvers. Observations of the sun with XSM are planned according to the orbital seasons of the spacecraft and calibration observations with the on-board radioactive source is carried out at regular intervals to monitor the instrument performance. Calibration spectra corrected in pulse invariant channels at four instances are shown in figure 29. Figure 30 shows the spectral resolution (FWHM) and peak energy of the 5.9 keV line with time over the first six months of in-flight operations of XSM. This demonstrates that the instrument is operating very well with no degradation in performance and the gain estimates from ground calibration is able to provide accurate energy measurement.

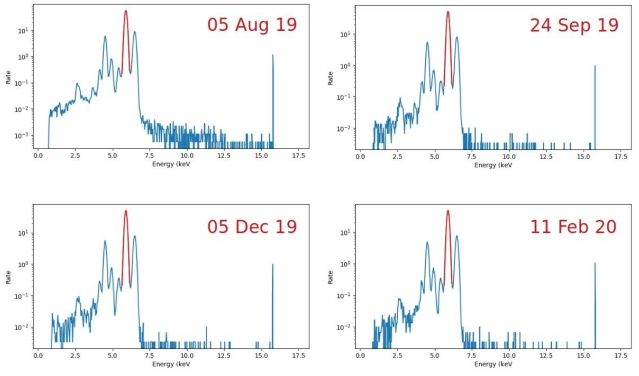


Figure 29: Calibration spectra of XSM obtained at different fines in-orbit. Spectral line at 5.9 keV is fitted with a Gaussian to obtain the FWHM and estimated peak energy.

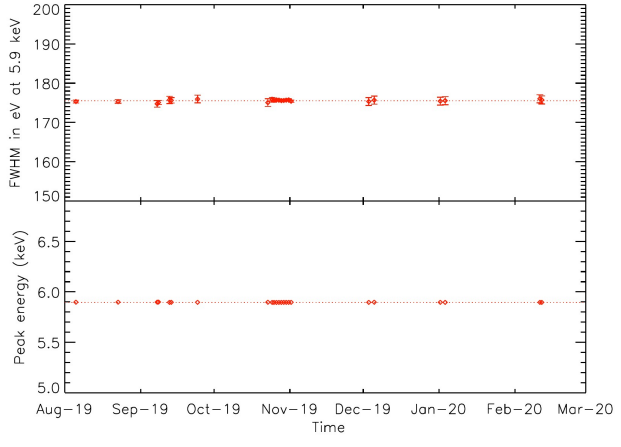


Figure 30: Full width at half maximum (top) and peak energy (bottom) of the 5.9 keV line from the on-board calibration source of XSM. Spectral performance of XSM matches with the ground calibration and has been stable during the in-flight operations.

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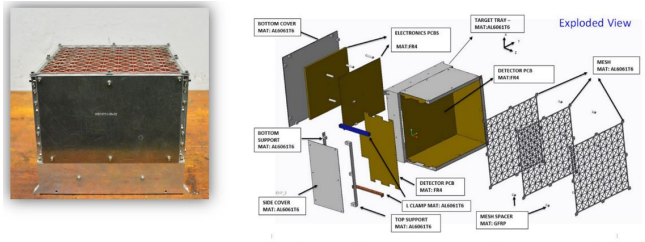
**(M. Shanmugam, S. V. Vadawale, N. P. S. Mithun, A. Patel, N. K. Tiwari, H. Kumar, S. K. Goyal, T. Ladiya, N. Singh, S. Kumar and D. K. Painkra)**

**VODEX Detector**

From the asteroid belt dust particles, those with size bigger than $\sim$0.1 $\mu$m travel inward toward Sun over a geological timescale and encounter various planets like Mars, Earth and Venus. The flux of these Interplanetary Dust Particles (IDPs) is not measured at Venus, expect a few spot measurements at larger distances from Venus. The IDPs are ablated after entering the Venusian atmosphere and contribute metal ions, giving enhancement in the conductivity profile. A Venus Orbit Dust Experiment (VODEX) is proposed for future Venus orbiter to study flux and distribution of high altitude dust at and around Venus and also between Earth and Venus. The detector of VODEX is optimized for the IDP flux, detector area as well as payload mass and it is developed for the demonstration in Earth environment. The detector has been analyzed and tested for the vibration levels of the PS4 of PSLV. The solar wind acts as noise for the dust detector and therefore, the detector has been simulated using Geant4 software to obtain the expected response of high energy solar wind particles using GOES data. The proton flux, alpha particles and GCR effect were studied. Further, the detector material damage was understood in the TRIM software using the ACE/GOES data in different energy levels. Figure 31 shows the detector, its exploded view and various results.




| Proton Energy (MeV) | SE Detached in Detector Space | % Electrons Detached |
|---|---|---|
| 0.01 | 0 | 0 |
| 0.1 | 0 | 0 |
| 1 | 144 | 1.44 |
| 2 | 341 | 3.41 |
| 5 | 390 | 3.9 |
| 7 | 344 | 3.44 |
| 10 | 344 | 3.44 |
| 20 | 1164 | 11.64 |
| 50 | 841 | 8.41 |
| 100 | 648 | 6.48 |
| 200 | 664 | 6.64 |
| 500 | 601 | 6.01 |
| 1000 | 654 | 6.54 |
| Proton impact simulated by GEANT4 generates only secondary electrons | | |

| Energy Range | Proton Flux * (# cm$^{-2}$ sr$^{-1}$ s$^{-1}$) | Damage using TRIM (Vacancy/Impact) | % Damage of Detector in 10 Years |
|---|---|---|---|
| 47-68 keV | 166.2 | 15.8 | 5.85 E-6 % of Au |
| 115-195 keV | 2.95 | 21 | |
| 310-580 keV | 1.05 | 29.8 | |
| 1 - 5 MeV | 1.56 | 43.5 | 9.59 E-7 % of Cu |
| 5 - 10 MeV | 0.21 | 56.8 | |
| 10 - 30 MeV | 0.17 | 43.05 | |
| 30 - 50 MeV | 0.12 | 9 | 1.65 E-8 % of insulator |
| 50 - 100 MeV | 0.06 | 4 | |
| 100 - 500 MeV | 0.02 | 1.35 | |
| Damage study of dust detector using TRIM software shows that damage done in 10 years due to solar wind proton is negligible. | | | |
| *ACE/GOES Data[40] | | | |

Figure 31: VODEX detector, its exploded view and various results like the noise and damage in response to the high energy solar wind particles.

In addition, the detector bias was optimized based on the detector geometry and capture of charge carriers after the impact. The value of bias voltage decides the efficiency of collection of ions and electrons and hence is a very important parameter. Simulations were carried out to optimize the bias voltage using SIMION software. The Figure 32 shows the meshed detector in SIMION software. As we increase the bias voltage from 50 V to around 200 V, the collection efficiency increases. After that, there is no considerable increase in the efficiency on increase of bias voltage. This result is also depicted in Figure 32. There are two opposite factors, which govern this capture efficiency:

- The plate with higher bias will tend to attract and collect more of the oppositely charged particles.

- The same higher bias will, on the other hand, repel and hence reduce the capture of particles with same polarity.

The choice of bias voltage should be done such that the collection efficiency is higher and on the other hand, the bias voltage is lower possible, so that requirement of additional resources can be avoided.

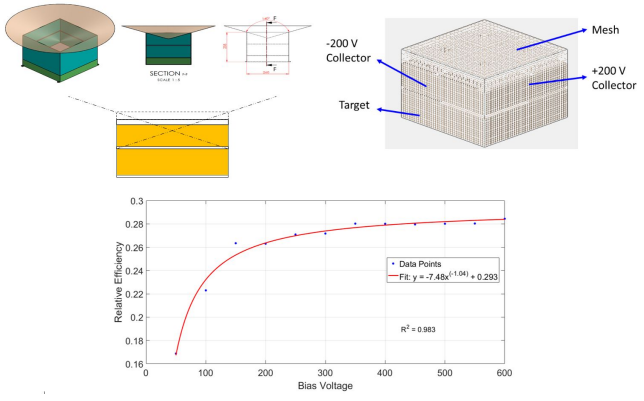



Figure 32: VODEX detector geometry, its optimization in the SIMION software and its capture efficiency.

**(J. P. Pabari, S. Nambiar, S. Jitarwal, Rashmi, Kevikumar Lad, K. Acharyya, V. Sheel, R. Mahajan, A. Bhardwaj, S. M. K. Praneeth, B. Shah, J. Rami, V. Singh, R. Singh, S. A. Haider, B. M. Pandya, A. Kumar and Team)**

### VODEX Electronics

The electronics design of the VODEX is shown in Figure 33. The analog electronics was designed and tested in the laboratory. The impact signal detected by detector is amplified by the Front End (FE) electronics. The charge collected by collector is fed to Charge Sensitive Preamplifier (CSPA), followed by a Buffer, used for impedance matching. The signal is then fed to Analog to Digital Converter (ADCs) after adding two ion channel (IC) and electron channel (EC) signals from four collector plates. The third channel or Noise channel (NC) follows a similar pattern. The signal from front end electronics is fed to high speed ADC. Post digitization the signal is processed using FPGA and relevant signals are stored in the memory which is then transferred to spacecraft memory. Two DC-DC converters are used to bias the detector at appropriate voltage which is in turn controlled by two Digital to Analogue Controllers (DAC).

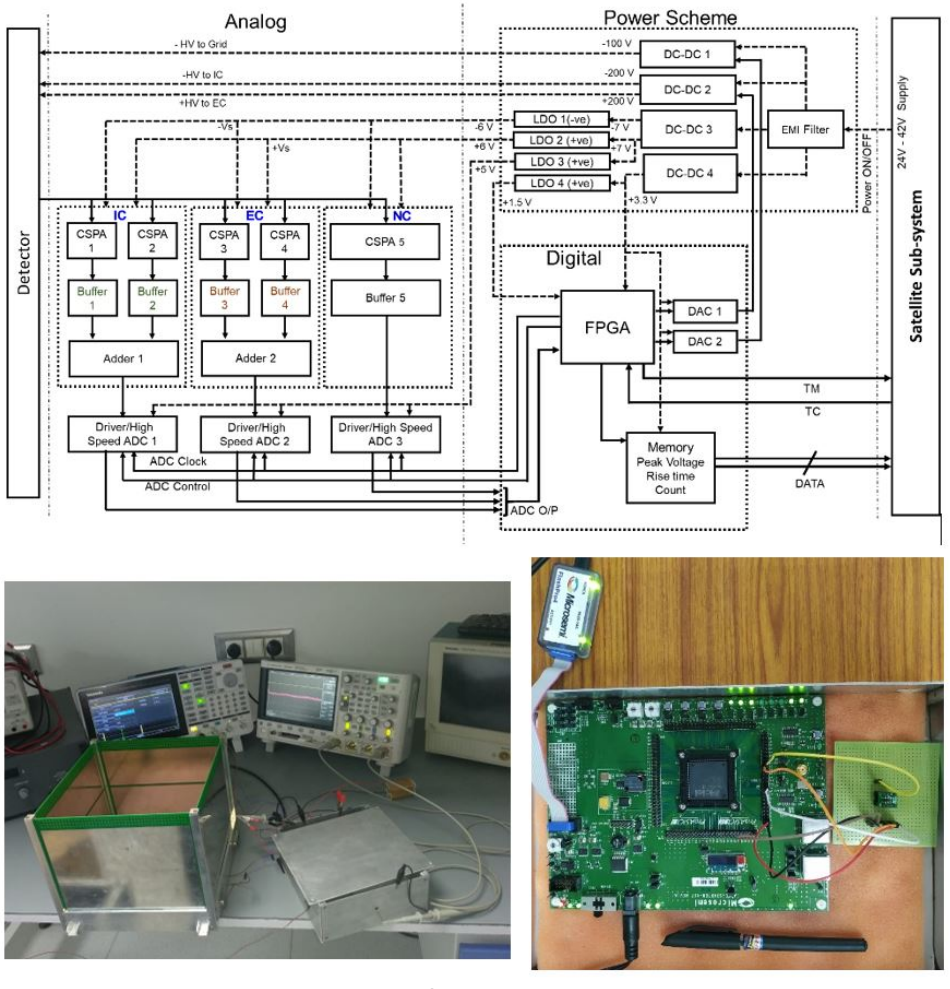



Figure 33: VODEX electronics design

The front end and processing packages are powered using other two DC-DC converters where Linear Drop-Out (LDO) Voltage regulators are used to regulate the supply voltage to crucial components. An EMI filter is used between spacecraft supply and DC-DCs to avoid any surge in supply damaging the components. The VODEX testing results are shown in Figure 34.

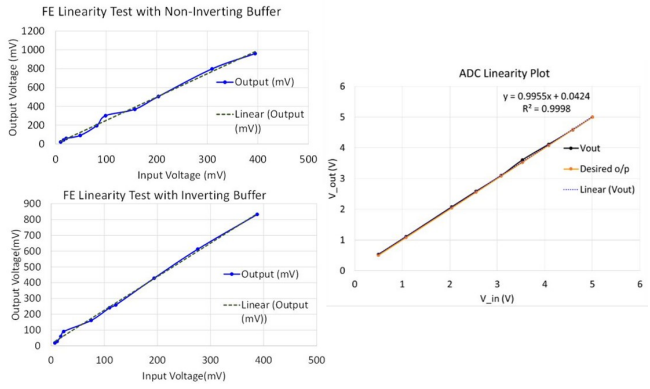



Figure 34: VODEX testing results

**(J. P. Pabari, S. Nambiar, S. Jitarwal, Rashmi, K. Acharyya, V. Sheel, R. Mahajan, A. Bhardwaj, S. M. K. Praneeth, B. Shah, J. Rami, V. Singh, R. Singh, S. A. Haider, B. M. Pandya, A. Kumar and Team)**

### VODEX Testing

The dust detector has been tested extensively using a nanosecond pulse laser at IPR. Figure 35 depicts the experimental set up using a Nd: YAG pulse laser.

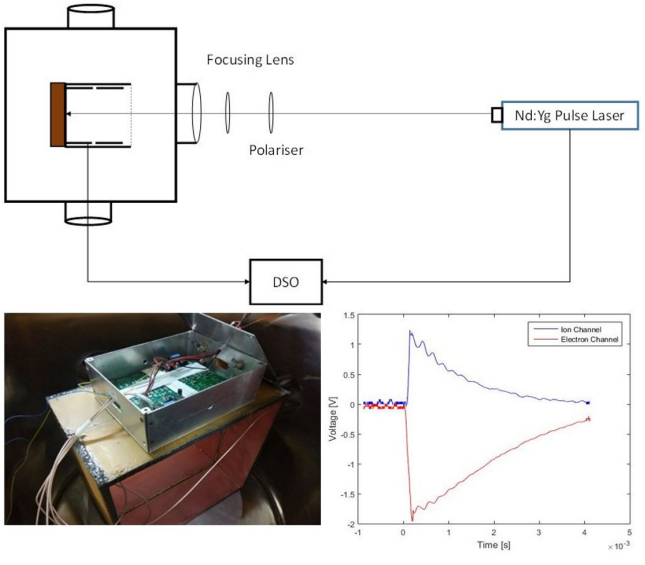



Figure 35: Optical set up of dust detector testing using Nd:YAG pulse laser with 1064 nm wavelength, detector and electronics inside the vacuum chamber and testing results.

The electrons and ions generated by the material ablation are captured using biased electrodes of the dust detector. The responses are processed in the processing electronics, which is also kept inside the vacuum chamber. The outputs from dust detector and trigger pulse of the laser are displayed on an oscilloscope and the data are analyzed offline.

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### Radio Occultation Experiment

The atmospheric density profile can be studied by a Radio Occultation (RO) experiment using a satellite platform. Whenever spacecraft passes behind a planet, near the periapsis, a microwave signal is transmitted from the transmitter on board. The signal is received at the ground station on Earth, which passes through the planetary atmosphere. While passing through the atmosphere, the signal is bent due to refraction caused by the atmospheric species. The phase of received signal caries the information, from which the atmospheric profiles are generated. We have initiated design and development of an RO transmitter operating in X-band. A laboratory model was demonstrated using COTS components to work at 8.4 GHz frequency, as shown in Figure 36. The important device of the RO transmitter is an Ultra Stable Oscillator (USO) which has the Allen variance in the range of $\sim 10^{-13}$ for the short term operation, useful for the observation.

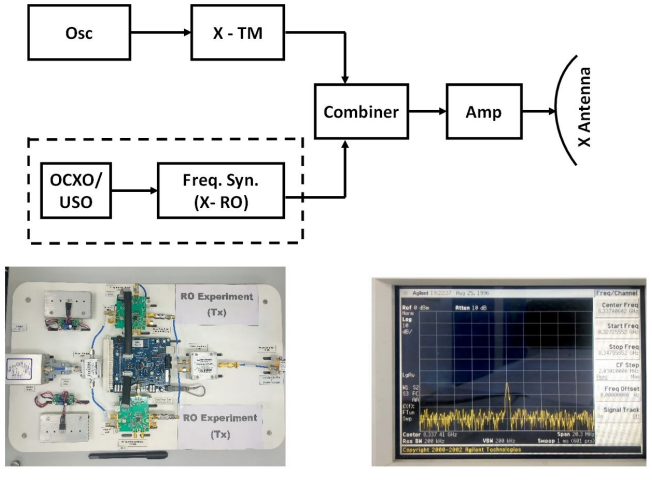



Figure 36: Design blocks of RO instrument, a laboratory model of the transmitter and testing results.

The model shown in Figure 37 is based on a Phase Locked Loop (PLL) technique, a newer one for the realization of RO instrument, proposed for the space applications. In the conventional approach, a multiplier based technique is used whose design has been completed, as shown in Figure 37. The basic signal frequency is multiplied and filtered in a chain of multipliers band pass filters. The amplifier at the end of the chain is used to compensate the signal loss and also, to make it to the level required by the combiner. In this case, a basic frequency of 58.35 MHz is suggested to finally achieve the RO frequency of 8402.4

MHz, which falls within the downlink band of 8400-8450 MHz at the IDSN Byalalu near Bengaluru. The further work is underway.

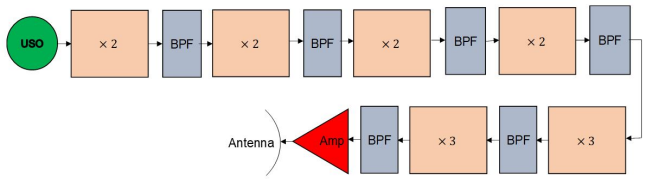



Figure 37: Multiplier based design of an RO instrument

**(V. Sheel, J. P. Pabari, S. Jitarwal, S. A. Haider and Team)**

### Diplexer for Radio Occultation Experiment

When a spacecraft passes behind a planet, radio waves passing through atmosphere experiences a bending. There occurs a small changes in frequency ($\Delta$f), transmitted by spacecraft and received at a ground station on Earth. This change in frequency, Doppler, provides the properties of atmosphere through which the radio signal propagated. For transmission and reception of the radio signals there are four possible combinations on board as tabulated in Figure 38.

| Instrument Option | |
|---|---|
| Tx (Single) On Board | Tx (Double) On Board |
| Rx (Single) On Board | Rx (Double) On Board |

Figure 38: On Board Transmit/ Receive Communication Instrument

In case two separate frequency channels are utilized on-board then diplexer separates the frequencies as illustrated in Figure 39.

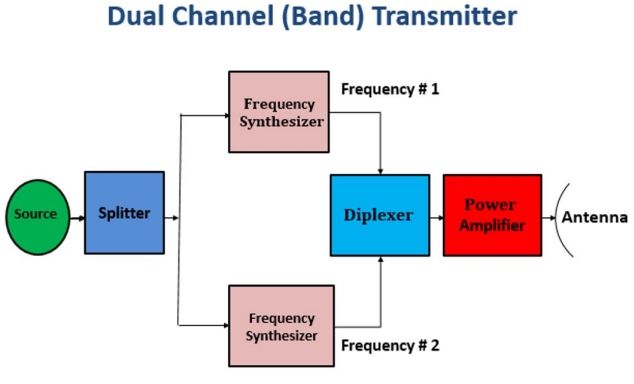



Figure 39: Diplexer in a dual-channel transmitter

The diplexer filter is primarily a three ports frequency dependent device, which provides two pass bands, with one common port. The purpose of a diplexer is usually of force a frequency specific impedance to occur at the input port. The branch filters of a diplexer are synthesized by single terminated network and usually they have a symmetric structure as illustrated in Figure 40.

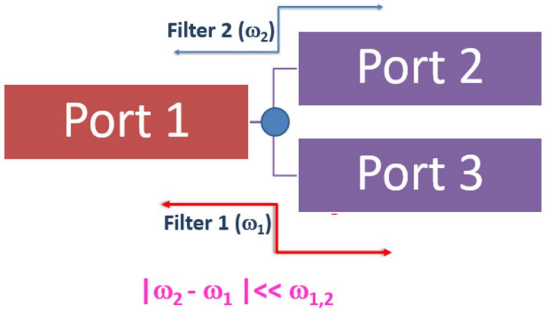
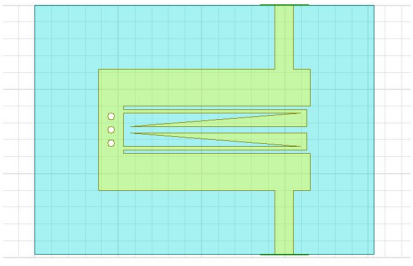



Figure 40: Port Isolation in Diplexer

A pass-band filter was designed to permit radio occultation frequency band at around 8 GHz as illustrated in Figure 41 (a) whose X-band passband is illustrated in Figure 41 (b).



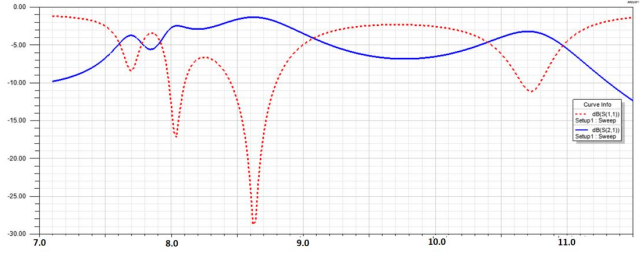



Figure 41: X-band Filter (a) Design of Filter at RO Frequency, (b) Passband of the Filter

The filter was further extended using self-similar structure to design the Diplexer. The optimized diplexer which is separating C-band Frequency and X-band frequency is depicted in Figure 42 (a).

The return and insertion losses of the Diplexer are depicted in Figure 42 (b). It was observed that maximum surface current persist in the central strip of the diplexer. The strip width was increased to analyze the effect on diplexer performance. Q-factor of the diplexer, as shown in Figure 42 (c), was decreasing with the increase in the strip width as effective capacitance of the structure gets reduced. The diplexer can further be optimized to separate out 8404 MHz and 8440 MHz frequencies useful in the Radio Occultation.

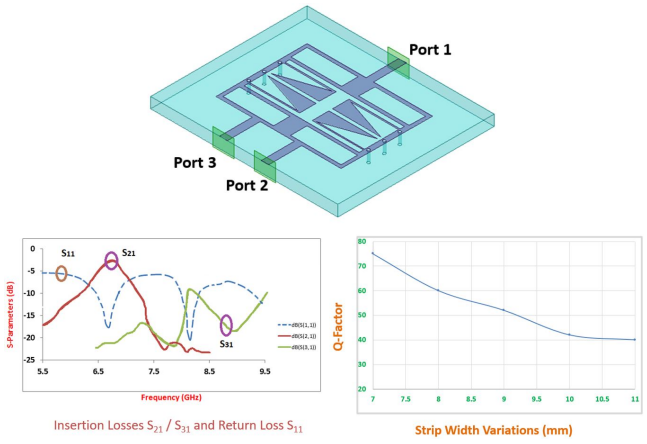



Figure 42: (a) 3-D View of Diplexer, (b) Diplexer Return and Insertion Losses and (c) Variation in Q-Factor of Diplexer with Strip width

This work has been led by Dr. Trushit Upadhyaya, Department of Electronics Engineering, CHARUSAT, Changa, Nadiad.

**(V. Sheel, J. P. Pabari, S. Jitarwal, S. A. Haider and Team)**

### Study of Lightning on Venus and LIVE

Lightning on Venus is yet be understood in detail, though some observations exist. The lightning discharge can produce the Schumann Resonance in the Venusian ionospheric cavity. The Maxwellian equations of electromagnetic waves, oscillating within the heterogeneous cavity formed in the lower atmosphere of Venus, are used to determine the Schumann Resonance modes.

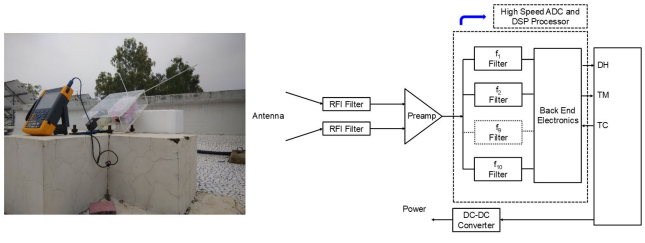



Figure 43: Demonstration of a laboratory model of LIVE kept on terrace of PRL Thaltej campus and design diagram of the LIVE engineering model

Further, analysis work has been initiated for the Venusian lightning. Some past observations exist, suggesting lightning activity in night side of Venus. The flash rate, strength, cloud model etc are yet to be fully understood on Venus. A Lightning Instrument for Venus (LIVE) for future orbiter is proposed to study the lightning on Venus in ELF-VLF frequency range. A laboratory model of LIVE was demonstrated working successfully for detection of natural lightning on Earth. The engineering model of the LIVE has been initiated, whose design diagram is shown in Figure 43. The sensing element of the instrument is an antenna, made from a solid cylindrical rod arranged in a Vee shape. The antenna was optimized for its operation by analysing different types of antennas. Optimization of other elements like matching network and Automatic Gain Control (AGC) are ongoing.

**(J. P. Pabari, T. Upadhyaya, S. Jitarwal, S. Nambiar, Rashmi, K. Acharyya, V. Sheel, A. Bhardwaj, S. A. Haider, and Team)**

### Electrically Short Dipole Antenna for Lightning Detection

A Lightning Instrument for VEnus (LIVE) is being developed at PRL. An electrically short dipole antenna is designed to receive/detect the lightning pulse possible to occur in Venusian environment. Numerous antenna configurations were designed and implemented having equal electrical length. The antennas were simulated and multiple iterations were carried out to optimize the antenna performance. These antennas were tested at PRL, Thaltej campus using Van-de-Graaff generator. The induced voltage across antenna terminals was recorded on oscilloscope for the further analysis. The antennas were fabricated at PRL Thaltej workshop; having an electrical length of 75 cm, diameter of antenna rod is around 4 mm, angle between two antenna arm is $60^{\circ}$ and material is Aluminium (with material density of 2.7 g/cm$^3$). All antennas are to be tested in the same environmental condition with similar set up. The Electrically Small Antennas (ESAs) are quite useful because of their compact size and ability to easily integrate with electronic circuits. The primary utilization of electrically small antennas is to accommodate within the satellite on-board physical size constraints. Few of the examples of omni-directional ESAs are electrically short half-wavelength and quarter-wavelength dipoles. The antenna is said to be electrically small, when its dimensions are much smaller than their wavelength (typically lesser than $\lambda/10$). Development of ESA (Figure 44) need special considerations, the design engineers need to address the trade-off between antenna size and practical antenna requirements. The prime drawback of electrically small antenna design is that size miniaturization comes with sacrifice in bandwidth, efficiency and hence gain. With decrease in electrical size of the antenna, radiation resistance decreases and reactance increases. This causes efficiency to reduce and increase in Q-factor.

In case of antennas, radiation pattern plays a major role. Radiation pattern defines the distribution of power outflowing (radiated) in case of transmitting antenna and incoming (received) in case of receiving antenna as a function of direction angles from the antenna. Antenna radiation pattern (antenna pattern) is defined for large distances from the antenna. The Radiated Field has figure of eight and possess Omnidirectional Pattern in one plane. Essentially Omni directional antennas are required to detect lightning in Hz-KHz range. A full-wavelength dipole antenna has higher directivity compared to the shorter quarter-wavelength or half-wavelength dipole antenna. Due to increase in the directivity, it takes larger antenna. With increase in the bulk-conductivity the antenna directivity increases. The directivity further increases with decrease in the angle between two arms of the dipole. The typical characteristic impedance start reducing from 75 Ω and tends to become smaller towards 50 Ω as the flare-angle becomes smaller. The 1.5 wavelength dipole radiation pattern is different compared to full wavelength. The pattern becomes maximum at around +45 and -45 degrees. The E-field has single vector component and hence the fields are said to be linearly polarized. Further, observation in x-y plane while dipole is oriented in z-plane, the field is present in y direction; therefore, the E-field is vertically polarized. The cut in 3-Dimension radiation pattern resembles donut and hence

often it is referred as donut-shaped radiation pattern (Figure 45). Due to extremely small in size, these dipoles are considered to be point sources, hence the gain of the antennas are 30 to 40 levels lower than the ideal isotropic radiator.

Figure 46 (a) shows the antenna test set up in open environment at PRL Thaltej campus and Figure 46 (b) represents the time domain pulse of various antenna configurations. Various color in Figure 46 (c) represents the results from different antenna configurations: yellow color shows cylindrical Vee antenna, green color represents folded dipole antenna & blue color represents the folded dipole Vee shape antenna. The time domain pulse defines the amplitude of induced voltage across the antenna terminals with respect to time. The cylindrical Vee electrically small dipole antenna is suitable on-board candidate.

This work has been led by Dr. Trushit Upadhyaya, Department of Electronics Engineering, CHARUSAT, Changa, Nadiad.

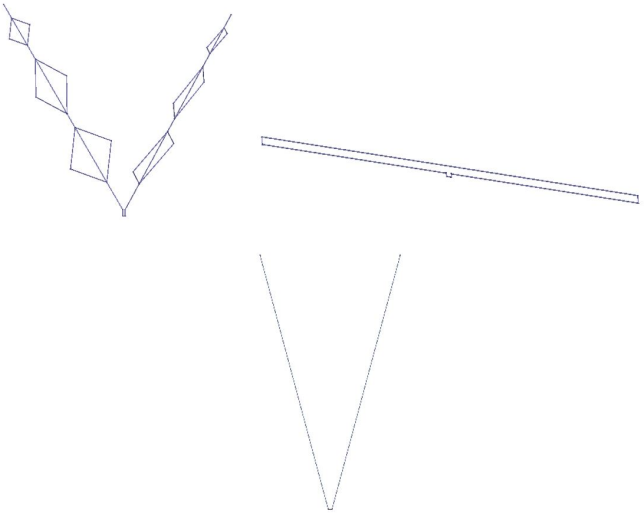


Figure 44: Perspective view of electrically small dipole antennas (a) Rhombus Dipole Antenna, (b) Folded Dipole Antenna, (c) Vee Dipole Antenna.

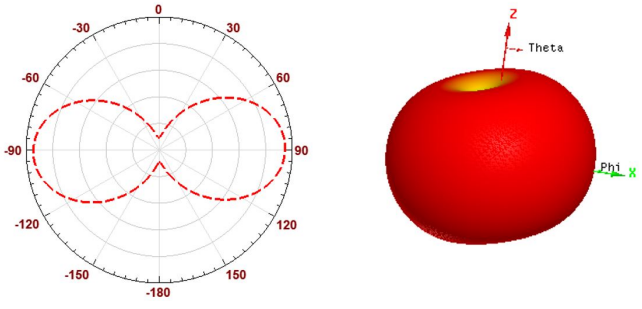



Figure 45: (a) 2-D Radiation Pattern of Dipole antenna and (b) 3-D Omni-Directional Radiation Pattern of Dipole antenna

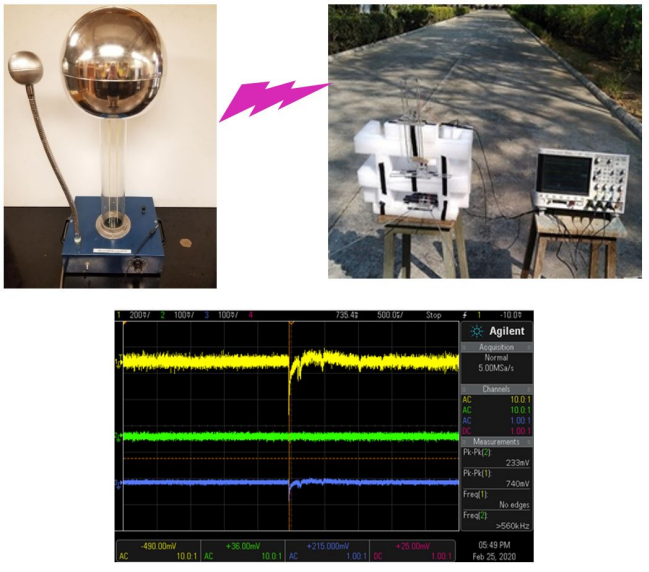



Figure 46: (a) Antenna Test Measurement in an Open Environment at PRL Thaltej campus and (b) Time domain signal of tested antenna configurations

**(J. P. Pabari, S. Jitarwal, S. Nambiar, Rashmi, K. Acharyya, V. Sheel, A. Bhardwaj, S. A. Haider, and Team)**

**Automatic Gain Control in Lightning Detection Instrument**

Automatic Gain Control (AGC) is a circuit design which maintains the equal level of amplification for input radio frequency. If the signal is extremely low, then the AGC circuit will increase the level and if input signal is too high it will lower the gain to maintain a constant output level. The AGC principle has been widely used in Amplitude Modulation (AM) receivers. Automatic gain control adjusts the received signal strength in the receive chain, either via analog or digital gain, to a certain desired power suitable for the best performance. The gain lineup is manipulated up or down while maintaining the best possible Signal-to-Noise Ratio (SNR). At high input power, either due to the strong desired signal or blocker, the gain control algorithm may lower overall gain, for example, in order to minimize the degradation due to nonlinearity.

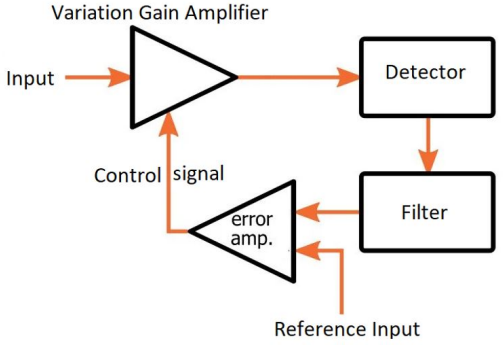



Figure 47: Design of automatic gain control for Lightning Instrument

In contrast, when the input signal power is low, the gain control algorithm may choose to boost the overall gain in the receiver chain in a manner that reduces the noise figure and boosts the SNR. For one of the approaches where separate channels are selected to receive the possible lightning frequencies, the Automatic gain control circuit has been developed as illustrated in Figure 47. The circuit is capable of providing stable gain of around 45-50 dB to improve the Signal-to-Noise Ratio.

This work has been led by Dr. Trushit Upadhyaya, Department of Electronics Engineering, CHARUSAT, Changa, Nadiad.

**(J. P. Pabari, S. Jitarwal, S. Nambiar, Rashmi, K. Acharyya, V. Sheel, A. Bhardwaj, S. A. Haider, and Team)**

### ChaSTE FM integration and LTO measurements

PRL Ahmedabad and SPL/VSSC Trivandrum are jointly developed the ChaSTE (Chandras Surface Thermophysical Experiment) payload which has been flown on Chandrayaan-2 Lander. ChaSTE aims to measure the vertical temperature gradient and thermal conductivity within top 10 cm of the regolith. These measurements will enable us to estimate precisely the equilibrium boundary between external and heat fluxes on the Moon, particularly at a high-latitude location. The experiment deploys a thermal probe (with ten 4 wire Platinum RTD sensors and a heater) at the Chandrayaan-2 landing site.

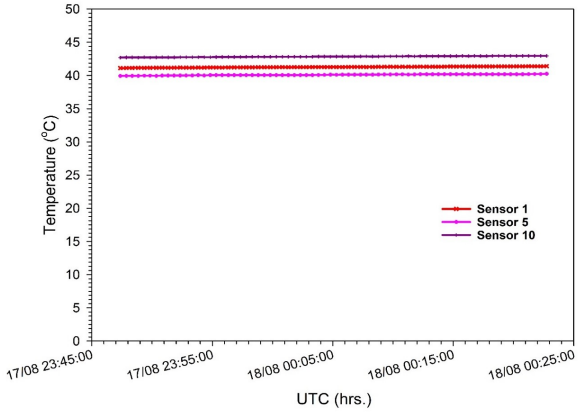



Figure 48: ChaSTE Temperature Measurements (3 Sensors) during LTO

The developmental details of the experiment have already been reported earlier. As done in the case of EM and QM models of FE electronics, the FM card of FE electronics has been delivered to SPL/VSSC for further integration with ChaSTE probe and processing electronics. After successful completion of all the qualifications tests on the payload as per CH2 ETLS, ChaSTE payload has been delivered to URSC clean room for further integration with the Chandrayaan-2 Lander. We have been continuously involved in all the integration and test activities of ChaSTE. Performance of the payload has been evaluated during all the pre-flight Integrated spacecraft tests (IST) carried out at both URSC, Bangalore and SDSC, SHAR. The functionality and performance was found to be as expected during all these tests. A payload operations centre (POC) has been setup at PRL, Thaltej Campus, for downlinking the ChaSTE and other payload data. A quicklook software has been developed to analyse the downloaded data from ChaSTE. During Chandrayaan-2s flight to the Moon, ChaSTE payload was switched for a couple of times during cruise phase as a part of payload health check tests. The temperature measurements obtained along the ChaSTE probe were analysed by comparing the temperatures with and found to be as expected. Figure 48 shows the stability of temperature measurements from 3 sensors on the ChaSTE probe which was switched on during Lunar Transfer Orbit. The temperature values were verified by the HK telemetry data with the nearby temperature sensors and show a good agreement implying a good health condition/operation of ChaSTE.

**(K. Durga Prasad, Chandan Kumar, Sanjeev Mishra, P. Kalyan S. Reddy, Arpit Patel, Tinkal Ladiya, M. Shanmugam, Mithun, Vinai K. Rai, S.V.S. Murty, C. Suresh Raju and ChaSTE Team, SPL/VSSC)**

### Development of a start-up chamber for PETC feasibility study

A wide range of laboratory experiments under simulated environments are now indispensable in order to comprehend remote/in-situ investigations planned in near future. Although ground truth is obtained by a few in-situ studies, interpretation of results and derivation of useful information certainly requires support from the data obtained through several laboratory experiments conducted on samples under simulated environments which necessitates the development of a dedicated facility/chamber to carry out such experiments. Also considering a futuristic scenario, where there will be planetary missions with several instruments aimed for in situ atmospheric and surface studies, it is logical to have a test facility where these instruments can be tested for their performance and well-calibrated before being flown.

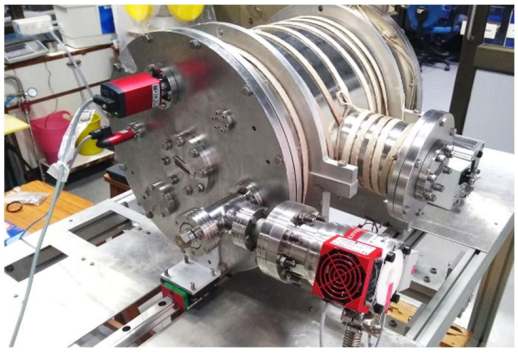


Figure 49: Start-up chamber for feasibility study of PETC developed at PRL undergoing baking

For this purpose, a large-scale Planetary Environment Test Chamber (PETC) is envisaged to be developed 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. One of the key aspect is that the environments to be simulated may sometimes contain gases that are toxic and destroy the standard pumping systems used in the thermo-Vacuum chambers. Other aspects are the design and

selection of chamber material, creating a desired composition of gases and holding the composition within the permissible limits, designing a thermal circuit to maintain the required temperatures within the chamber, introducing the corrosive and acidic gases in trace levels and condensing them when needed are some of the challenges to be addressed in the development of this chamber. As a startup activity for the PETC, we have indigenously built a small cylindrical prototype chamber of 40 cm diameter and 50 cm length for feasibility study. This prototype chamber has been assembled and currently being tested and found to maintain a dynamic vacuum of better than $10^{-5}$ torr and a static vacuum better than $10^{-3}$ torr. This was achieved through a series of design/assembly changes and long-term baking. The chamber is provided with rail-mounted doors on both sides. Several conflat ports of different sizes (DN16CF, DN40CF and DN63CF) have been machined on both the doors for facilitating connections to input gas lines from manifolds, vacuum pumps and gauges, monitors, instrumentation and other feedthroughs etc. A glass viewport on a DN163CF conflat port is also provided on one side of the chamber. The chamber uses a turbopump and rotary pump assembly in series to maintain the required vacuum. Even with the massive work volume of this chamber, the high vacuum of the order $10^{-5}$ torr is achieved within five minutes of pump operation. This is invaluable in conducting experiments with timescales of hours. Work related to maintaining the thermal circuit and gas mixing is currently underway. Figure 49 shows the picture of the developed chamber currently undergoing testing.

**(K. Durga Prasad, Janmejay Kumar, P. Kalyan S. Reddy, Chandan Kumar, Sanjeev Mishra, Vishnu Patel, H. R. Vaghela, Varun Sheel, S. A. Haider, A. Bhardwaj)**

# Space and Atmospheric Sciences

**Spatial, seasonal, and altitudinal heterogeneity in aerosol-induced atmospheric heating rate**

In the present work the significance of single scattering albedo (SSA) in estimating atmospheric heating rate over an urban (Ahmedabad) and a high-altitude remote location (Gurushikhar) is examined with an objective to investigate its spatial, seasonal and altitudinal heterogeneity.

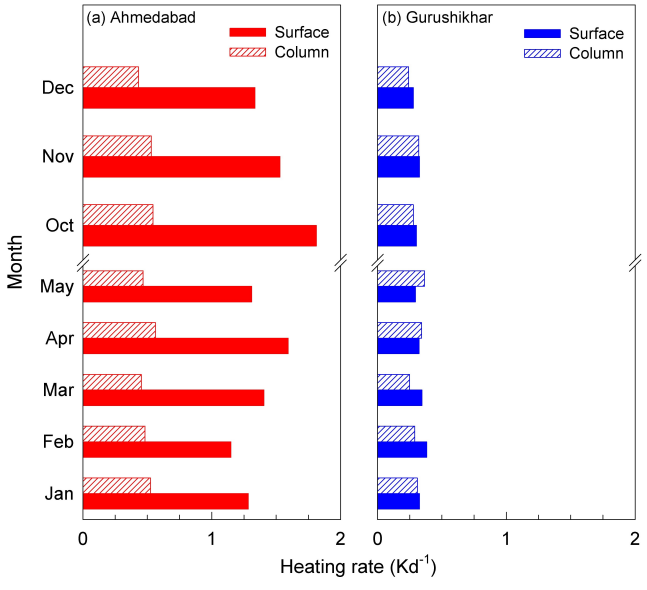



Figure no.1: Monthly mean aerosol-induced atmospheric heating rate ($Kd^{-1}$) estimated using surface and column single scattering albedo (SSA) over (a) Ahmedabad and (b) Gurushikhar.

The data used are near surface (estimated from the surface measurements of aerosol scattering and absorption coefficients) and column (retrieved from the satellite-borne Ozone Monitoring Instrument sensor). The monthly mean atmospheric heating rate estimated using surface SSA exhibits strong seasonal variation over the urban Ahmedabad. The heating rate is maximum during October over Ahmedabad, consistent with lower SSA. The heating rate computed using column SSA is lower by a factor of 3-7 when compared to the heating rate computed using surface SSA, as column SSA is higher (figure 1). The monthly mean heating rate estimated using column SSA is found to be the highest during April over Ahmedabad when the AOD is maximum. On the contrary, the heating rate is maximum during November over Gurushikhar, which is consistent with the lower column SSA. The monthly mean atmospheric heating rate estimated using column SSA is lower by a factor of 1.5 when compared to surface SSA over Gurushikhar. The aerosol heating rate over Ahmedabad is a factor of 2 higher than Gurushikhar as SSA is lower which occurs due to a higher amount of absorbing aerosols (mainly black carbon). The annual mean atmospheric heating rate estimated using surface SSA is found to be 1.43 $\pm$ 0.21 and 0.32 $\pm$ 0.01 $Kd^{-1}$ , while atmospheric heating rate estimated using column SSA is found to be 0.50 $\pm$ 0.03 and 0.30 $\pm$ 0.02 $Kd^{-1}$ over Ahmedabad, and Gurushikhar, respectively. The study quantifies the variations in atmospheric heating rate that arise due to the differences in SSA on temporal (season), spatial (urban vs. high altitude remote) and on vertical (surface vs. column) scales. These results on aerosol-induced atmospheric heating obtained over the same region over distinct environments (locations), therefore, provide regional bounds and useful for regional climate impact assessment.

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**(T. A. Rajesh and S. Ramachandran)**

**Size resolved variation of refractory black carbon, and non-refractory aerosols over an urban environment**

Using a measurement setup that comprised state-of-the-art instruments, namely, a differential mobility analyzer (DMA) and a single particle soot photometer (SP2) size resolved variation of black carbon aerosols and the other non-refractory aerosols over an urban environment is studied. Aerosols of size 70, 100, 200, 300, 400 and 500 nm were selected using DMA and further size selected refractory black carbon (rBC) mass concentration, and mixing state quantification was done using SP2.

Results show that rBC mixing characteristics are different for different sizes of particles which would result in large variations in the physicochemical properties (i.e., hygroscopic and optical properties) of aerosols (figure 2). In general, rBC is a primary emission upon which other non-refractory components condense to form aged or internally mixed aerosol. Our observations revealed that rBC accounts for $\sim$80% of the observed Aitken ($<$100 nm) mode aerosol population. This shows that the nature of the combustion process and rBC population changes with size and has implications for both direct and indirect radiative forcing. Moreover, these results are crucial when determining the BC impact on cloud condensation nuclei (CCN) activation process and hence the aerosol indirect effect. These findings from an urban location in the tropics are the first and

unique, and are important in the context of resolving aerosol radiative properties more explicitly. These finfings are important in the context of hygroscopic and optical properties of rBC, core-shell mixed and non-refractory aerosol population with respect to their size from an urban location. This size selective aerosol mixing state information can serve as inputs in climate models for aerosol-cloud-radiation interaction studies.

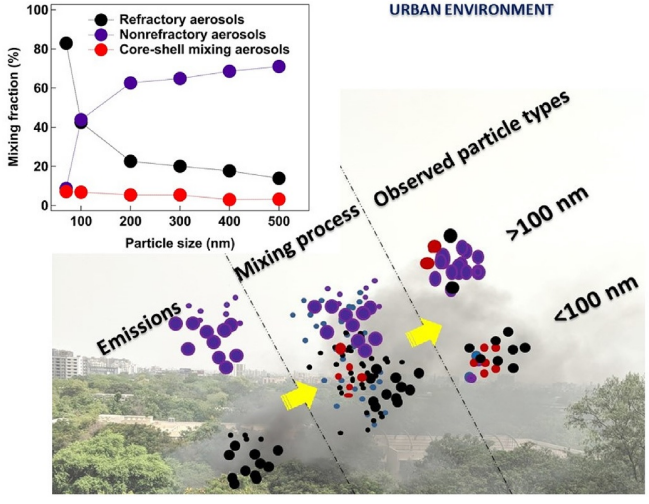


Figure no. 2: A schematic illustration of the size resolved variation of refractory black carbon (rBC) (both externally and internally mixed) above and below 100 nm size, and non-refractory aerosol over the urban Ahmedabad.

doi : https://doi.org/10.1016/j.apr.2019.12.006

**(B. Sarangi, S. Ramachandran, T. A. Rajesh and Vishnu K. Dhaker)**

### Extensive and intensive properties of aerosol over distinct environments

A study on extensive and intensive properties of aerosols are simultaneously carried out over a source region (urban environment - Ahmedabad), and background site (a high altitude remote location - Gurushikhar) to characterize their spatial and temporal variabilities. The scattering ($\beta_{sca}$) and absorption ($\beta_{abs}$) coefficients are termed the extensive properties of aerosols, whereas, single scattering albedo (SSA), Ångström exponent ($\alpha$), backscatter fraction (b), and asymmetry parameter (g) are known as the intensive properties of aerosols. The extensive properties, $\beta_{sca}$ and $\beta_{abs}$, exhibit strong temporal variation over Ahmedabad due to diurnal variations in emission sources and their strengths, and atmospheric boundary layer dynamics. On the contrary, over Gurushikhar, $\beta_{sca}$ and $\beta_{abs}$ exhibit peculiar diurnal variability with higher afternoon values as compared to forenoon and night because of fully evolved atmospheric boundary layer, in the afternoon, which accompanied with strong thermal convection aid an upward transport of aerosols to the mountain site from the surrounding foothills during afternoon hours. $\beta_{sca}$ and $\beta_{abs}$ over Ahmedabad are always higher by a factor of 3-5 than Gurushikhar. Gurushikhar SSA is higher than Ahmedabad due to the dominance of absorbing aerosols over Ahmedabad from the anthropogenic emissions (figure 3). $\alpha$ and b exhibit morning and evening peaks, whereas, g shows corresponding dips which coincide with the peaks observed in aerosol scattering and backscattering coefficients over Ahmedabad. Over Gurushikhar, the diurnal variation in $\alpha$, b, and g do not exhibit noticeable morning or evening peaks. The morning and evening peaks in $\alpha$ and b, and dips in g suggest the dominance of smaller size aerosols over urban, Ahmedabad. b values over Gurushikhar and Ahmedabad are similar suggesting that the aerosol backscatter fraction is regionally homogeneous over western India.

The inter-annual variability in the extensive and intensive aerosol properties is estimated to be less significant ($<$10%) over the high altitude region when compared to the source region, thereby, suggesting that the extensive and intensive aerosol properties over the high-altitude remote location can be classified as regional representative background.

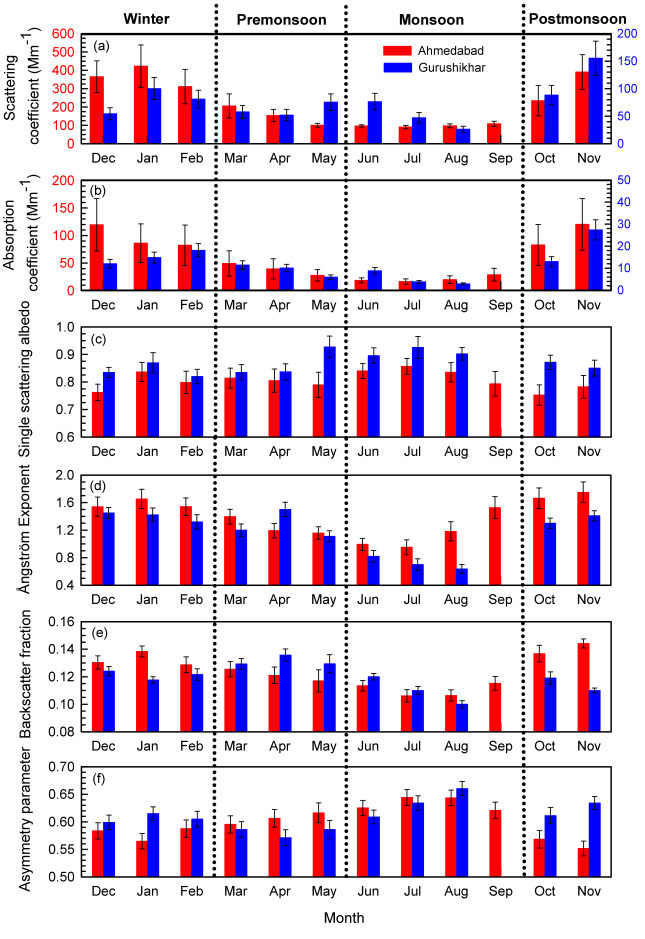


Figure no.3: Monthly mean variations in (a) aerosol scattering coefficient (Mm$^{-1}$), (b) absorption coefficient (Mm$^{-1}$), (c) single scattering albedo, (d) Ångström exponent, (e) backscatter fraction, and (f) asymmetry parameter at 0.55 $\mu$m over Ahmedabad and Gurushikhar. Vertical bars represent $\pm 1\sigma$ standard deviation from the mean. Scale on the y-axis (red) corresponds to Ahmedabad and the scale on the alternate y-axis (blue) corresponds to Gurushikhar.

doi : https://doi.org/10.1016/j.jastp.2020.105223

**(T. A. Rajesh and S. Ramachandran)**

**Distribution of volatile organic compounds over Indian subcontinent**

Volatile organic compounds (VOCs) play vital roles in the atmospheric chemistry, air quality, and climate change, however, their spatial and temporal distributions are poorly characterized. The in situ observations have particularly been lacking over the Indian subcontinent where highly diverse biogenic and anthropogenic emissions influence the VOCs. In this direction, we studied the distribution of VOCs over Indian region during winter conditions (January 2011) combining the regional model WRF-Chem (Weather Research and Forecasting model coupled with Chemistry) with ground- and space-based observations. Figure 4 shows the WRF-Chem simulated mean distribution of two VOCs: ethene and propane over the Indian region together with measured values at few stations. WRF-Chem simulated distribution of VOCs agrees to an extent with available measurements over contrasting environments of the Indian subcontinent. Model revealed elevated VOC loadings over the Indo-Gangetic Plain and the northeast regions than those over the other parts of the Indian subcontinent. In general, the relative abundance of propane (27-31%) and ethane (13-17%) are found to be higher across the Indian region. Further the western coast, eastern India and the Indo-Gangetic Plain are identified as the regional hotspots of formaldehyde and glyoxal, in agreement with chemical reanalysis and satellite-based observations. The analysis suggests strong influences of anthropogenic emissions on VOCs over the Indian subcontinent, except the northeast- where biogenic emissions also had profound impact. The study highlights a need to initiate measurements of VOCs over the identified regional hotspots to validate the findings based on model simulations and satellite retrievals over the Indian region.

This work has been done in collaboration with Dibrugarh University (L. Chutia, B. Pathak, P. K. Bhuyan); Space Physics Laboratory, VSSC, Thiruvananthapuram (I. Girach); and University of Bremen, Germany (L. Alvarado, J. Burrows).

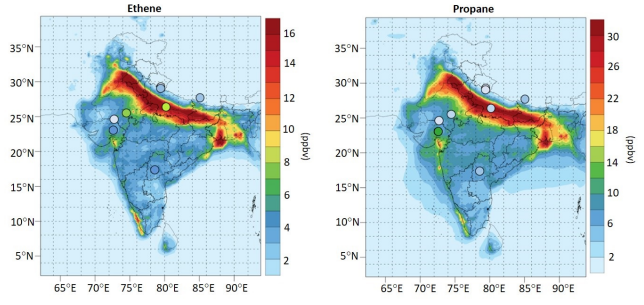


Figure no. 4: Distribution of ethene and propane over Indian region during January month simulated using the WRF-Chem model. Measured values over different stations are shown on similar color scale for comparison.

doi : https://doi.org/10.1016/j.envpol.2019.05.097

**(N. Ojha and L. K. Sahu)**

**Effect of dry deposition on surface ozone over the Indian region**

Surface ozone causes detrimental effects on human health and vegetation, besides playing a key role in the atmospheric chemistry. The main sink of ozone is through the dry deposition which depends on the land use and meteorology, other than chemical losses. We performed simulations using the regional model WRF-Chem (Weather Research and Forecasting Model coupled with chemistry) to compute the effect of dry deposition on ozone over the Indian region. It is estimated that the dry deposition reduces ozone levels by up to $\sim$40% over the Indo-Gangetic Plain and parts of western and central India. Additional difference of up to $\sim$5 ppbv in ozone is seen when dry deposition of ozone precursors is also switched off. A significant contrast on the effects of dry deposition is simulated over spatial as well as the temporal scales over this region. Ozone enhancements due to absence of dry deposition are less at urban stations during night than those at rural and high-altitude stations. Indian ecosystem is suggested to act as a key sink of ozone through the dry deposition process. The study fills a gap over the south Asian region, where dry deposition is anticipated to get perturbed due to potential changes in land use and land cover.

This work has been done in collaboration with IIT Madras (A. Sharma, S. S. Gunthe), Max Planck Institute for Chemistry, Germany (A. Pozzer), and Lancaster University, UK (T. U. Ansari).

doi : https://doi.org/10.1021/acsearthspacechem.0c00004

**(N. Ojha and S. K. Sharma)**

**High levels of isoprene in the marine boundary layer of Arabian Sea during spring inter-monsoon: Role of phytoplankton blooms**

The Arabian Sea possess an intense oxygen minimum zone (OMZ) due to high primary productivity. These important biogeochemical aspects of the Arabian Sea have led us to investigate air-sea exchanges over the region. The measurements of isoprene mixing ratio in marine air and biological parameters in seawater were conducted during the inter-monsoon period of April-May 2017 (Figure 5). The year 2017 was the second warmest year since 1880 for the global ocean with positive sea surface temperature (SST) anomalies over the Arabian Sea during the campaign. The overall variation of isoprene follows the distribution of Chlorophyll-*a* (Chl-*a*) with lower (0.38$\pm$0.14 ppbv) and higher (0.75$\pm$0.17 ppbv) values over central and northern regions, respectively. The diurnal pattern of isoprene covary with solar flux, equivalent potential temperature (EPT) and wind speed as the daytime mixing ratio was $\sim$55% higher than its nighttime value. Major enhancements ($>$0.6 ppbv) were associated with the blooms of *Trichodesmium* and *Thalassiosira* in oligotrophic conditions. High abundance of diatoms and cyanobacteria, intense solar flux and high SST favored the production of isoprene from microbial sources. The estimated emission fluxes of isoprene were in the range of $1.510^{7}$-$1.210^{8}$ molecules cm$^{-2}$ s$^{-1}$. Levels of isoprene in marine air and its emission fluxes were higher than the values reported for most of other highly productive oceans. This study highlights implications of "Arabian Sea Paradox" on regional atmospheric chemistry.

This work was done in collaboration with Dr. Ravi Yadav from Indian Institute of Tropical Meteorology (IITM), Pune and Kusum Komal Karati from Centre for Marine Living Resources and Ecology, Kochi.

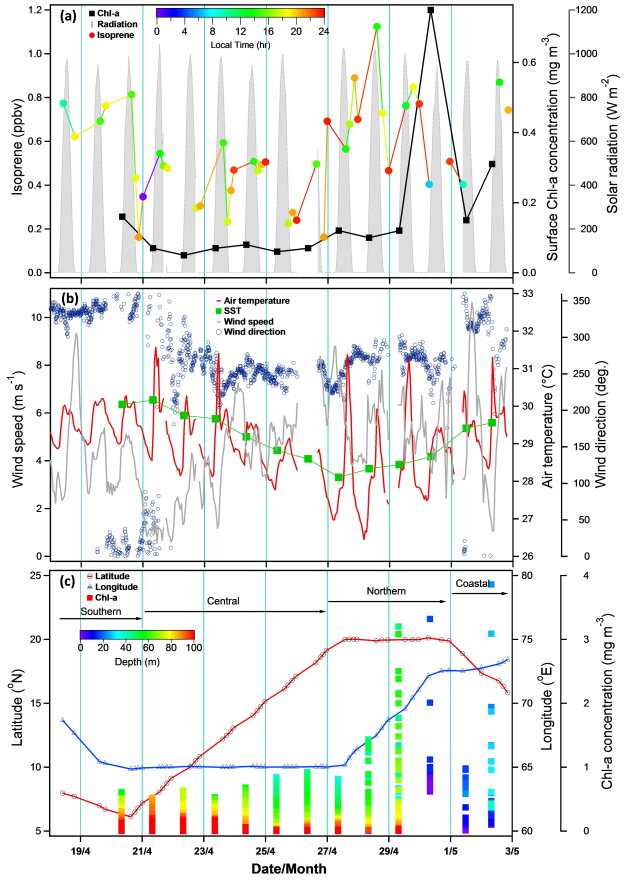


Figure no.5: Time series of (a) isoprene mixing ratio, surface Chl-a concentration (using fluorometer), and solar radiation flux, (b) SST and meteorological parameters, (c) Chl-a depth profile (using CTD sensor), and cruise parameters over the Arabian Sea during 15 April-2 May 2017.

doi : https://dx.doi.org/10.1021/acsearthspacechem.9b00325

**(Nidhi Tripathi, L. K. Sahu and Arvind Singh)**

### The influence of local meteorology and convection on carbon monoxide distribution over Chennai

The influence of local meteorology and convection activities on the vertical distribution of carbon monoxide (CO) over Chennai in southern India was investigated by analysing the measurements of ozone aboard airbus in-service aircraft observations during the years 2012-2013. The seasonal variation of CO in the free troposphere was observed to be different and less pronounced than that in the planetary boundary layer (PBL). The near surface mixing ratio of CO was the highest (190±68 ppbv) during winter, while enhanced values (117 ± 11 ppbv) in the free troposphere were observed during post-monsoon. The mixing ratios were the lowest throughout the troposphere during the monsoon. In the PBL, the mixing ratios of CO showed a decline with an increase in wind speed and were the highest (>200 ppbv) under stagnant conditions during winter. The higher CO in the lower free troposphere during the pre-monsoon period is attributed to the emissions of stronger biomass burning. In the middle-upper troposphere, higher levels of CO during post-monsoon are due to the enhanced vertical mixing of regional emissions associated with weaker wind shears and frequent convection activities. Overall, the contrasting effects of stronger CO emissions can be observed in winter/pre-monsoon, while the efficient vertical mixing during the monsoon/post-monsoon season governs the observed seasonality of CO. The model for ozone and related chemical tracers, version 4 (MOZART-4) provides a reasonable representation of the convection effect on the CO mixing ratio. This study highlights a need to conduct more observations, especially of aircraft-borne instruments, to understand the effects of regional-scale emissions and dynamics in the middle-upper tropospheric chemistry over South Asia.

doi : https://doi.org/10.1007/s12040-019-1156-z

**(L. K. Sahu, Nidhi Tripathi, Varun Sheel, and N. Ojha)**

### Sources of volatile organic compounds (VOCs) at urban and suburban sites of New Delhi in winter season

Vehicular emission is a significant source of ambient volatile organic compounds (VOCs), carbon monoxide (CO), and oxides of nitrogen (NOx) in the megacities of the world. New Delhi, located in the Indo-Gangetic plain (IGP), experiences a high loading of pollutants emitted from both local and regional sources in the winter season. However, the lack of information on real-world emission factors (EFs) for a typical urban is a hindering factor in the development of reliable emission inventory in India. The measurements of many important VOCs were conducted the urban site of Indian Institute of Technology Delhi (IITD) and at a suburban site of Manav Rachana University (MRU), Faridabad during winter (January-February) of the year 2018). We used high time- and mass- resolution Proton Transfer Reaction-Time of Flight-Mass Spectrometer (PTR-TOF-MS) for the measurements of VOCs at both the sites. The measurements were influenced mainly by local emissions but also from long-range transport. The short-term variations of VOCs reflect the change in local emissions and meteorological parameters. The mixing ratios of VOCs are particularly high during winter due to the lower planetary boundary layer (PBL) depths. In this study, we used the mixing ratios of benzene, acetonitrile, and isoprene as tracers to identify and estimate the contributions from vehicle exhaust, biomass burning, and biogenic sources, respectively. The contributions of traffic-related emissions (aromatic VOCs), estimated using the positive matrix factorization (PMF) receptor model, were ∼57% at the urban site, while ∼36.0% at the suburban site of New Delhi. Unlike aromatic VOCs, oxygenated-VOCs (OVOCs) exhibited significantly higher contributions during the daytime. The data have analyzed to investigate the role of secondary productions of OVOCs in the atmosphere due to photochemical aging.

This work is done in collaboration with researchers from Indian Institute of Technology Kanpur, Indian Institute of Technology Delhi, and Paul Scherrer Institute (PSI), Switzerland.

doi : https://doi.org/10.5194/acp-2020-11.

**(L. K. Sahu and Nidhi Tripathi)**

**Effect of dust induced ice-cloud modification on Indian summer monsoon**

The Indian summer monsoon is the central source of freshwater availability to the densely populated regions of southern Asia. The monsoon circulation and rainfall variability are widely known to be governed by large-scale atmosphere-land-ocean dynamics, meteorological processes, and air-sea interactions. In the past two decades, the role of atmospheric aerosols has emerged as a source of modulating monsoon rainfall, as suggested by a host of climate modeling studies. We have investigated a new aspect of aerosols in possibly influencing monsoon clouds and rainfall by specifically examining interaction between mineral dust aerosols and ice clouds, as part of the monsoon system. Using state-of-the-art information derived for aerosols and clouds from multi-sensor and disparate satellite observations spanning 11 years, we find characteristic signature of dust aerosol-induced modification of thick ice clouds (so-called cloud invigoration effect) toward strengthened susceptibility of monsoon precipitation. Overall, our results shed new light on the potential role of dust and ice cloud interactions in modulating the Indian summer monsoon.

This work was done in collaboration with Ritesh Gautam of Environmental Defence Fund, Washington DC, USA and Takuro Michibata of Research Institute of Applied Mechanics, Kyushu University, Japan.

doi : https://doi.org/10.1029/2018GL081634

**(Piyushkumar Patel and Harish Gadhavi)**

**A Rossby wave breaking-induced enhancement in the tropospheric ozone over the Central Himalayan region**

The high-altitude regions in the Himalayas are prone to high ozone concentrations frequently resulting from diverse dynamical and transport mechanisms. Here, we report an unusual enhancement in the surface and tropospheric ozone concentrations over the central Himalayan region from ground-based and space-borne measurements in the month of December 2010. The surface ozone levels ($\sim$80 ppbv) on 18-19 December 2010 is observed to be two-fold higher relative to the seasonal average (December-January-February) of about 40-50 ppbv in the central Himalayan region. The space-borne measurements from Tropospheric Emission Spectrometer and Ozone Monitoring Instrument onboard Aqua satellite also show higher values in the tropospheric column ozone over this region. The satellite observations indicate an increase in tropopause temperature of about 5 $^{\circ}$C and decrease in tropopause altitude about 1 km during 18-19 December 2010 resulting in the occurrence of tropopause fold facilitating the stratospheric-tropospheric exchange processes over the study region. The plausible reason for the occurrence of tropopause fold and subsequent enhancement of tropospheric and surface ozone is found to be associated with the breaking Rossby waves in the upper troposphere. The wave breaking leads to the advection of high-PV (potential vorticity) air, with magnitudes of about 3-4 PVU, towards the central Himalayan region from high-latitudes. The vertical component of PV advection also shows a deep stratospheric intrusion of high-PV air into the troposphere. The isentropic transport of ozone across the folding tropopause due to the wave breaking is clearly depicted from the satellite and reanalysis datasets. Therefore, the present study has strong implications of upper tropospheric wave dynamics to the tropospheric and surface ozone over the Himalayan regions having complex topography.

doi : https://doi.org/10.1016/j.atmosenv.2020.117356

**(Kondapalli Niranjan Kumar and Som Kumar Sharma)**

**Analysis of the middle atmospheric ozone using SABER observations: a study over mid latitudes in the northern and southern hemispheres**

The present study focuses on the middle atmospheric ozone variability using 14 (2002-2015) years of Sounding of the Atmosphere using Broadband Emission Radiometry onboard Thermosphere Ionosphere Mesosphere Energetics and Dynamics satellite observations over the mid-latitude regions of northern and southern hemispheres. It is noted that ozone buildup starts late winter, and peaks during the springtime and gradually decreases in summer to autumn transitional period in both the hemispheres. The time series of ozone indicates the dominant annual and semi-annual oscillations in the middle atmosphere. The annual oscillation (AO) is found to be dominant over both the hemispheres, while the semi-annual oscillation (SAO) peaks at two diferent altitude regions: 30-60 km and 80-100 km. Further, the amplitude of AO is much significant than SSAO and MSAO. It is also noted another significant oscillation that peaks at $\sim$4 months in the altitude range 60-80 km. The strength of these oscillations at different sites is studied by comparing it with the zonal mean spectrum to assess the longitudinal asymmetry. It is found that the longitudinal asymmetry is more significant in the northern hemisphere than the southern hemisphere. This can be attributed to the differences in the land (elevated topographies in the northern hemisphere) and primarily ocean (in southern hemisphere) contrast that further contributes to the differences in the strength of the vertically propagating planetary-scale waves modulating the middle atmospheric ozone.

doi : https://doi.org/10.1007/s00382-020-05124-6

**(Vaidehi Joshi, Som Sharma, and Kondapalli Niranjan Kumar)**

**Middle atmospheric planetary waves in contrasting QBO phases over the Indian low latitude region**

The present study primarily focused on the characteristics of the planetary scale waves in the middle atmosphere during different phases of Quasi-Biennial Oscillation (QBO), a dominant oscillation in the low-latitude stratospheric region. The temperature profiles retrieved from the Rayleigh lidar measurements have been utilized for the 11 winter periods between 1998 and 2009 over a low-latitude station, Gadanki (13.5$^{\circ}$N 79.2$^{\circ}$E). The spectral analysis of temperature anomalies indicates two dominant planetary-scale modes, namely, quasi 12-day and quasi 16-day waves. The existence of these waves in the middle atmosphere is strongly controlled by the westerly and easterly phases of QBO. For instance, the 12-day wave is mainly observed in the QBO westerly phase, while the 16-day wave peaks at two heights; 30-40 km and above 60 km with large spread in the mesosphere due to Doppler shifting in presence of westerly winds. The QBO easterly phase indicates low

wave activity with 16-day wave indicating appreciable amplitudes in the upper stratosphere and mesosphere and is absent in the lower altitudes. This indicates that the 16-day wave might be generated through some in-situ mechanism due to gravity breaking or instability in the mesospheric region. Moreover, the refractive index of the two dominant planetary waves are strongly negative in the easterly phase relative to the westerly phase of QBO in the lower troposphere and stratosphere. This indicates the high probability of the planetary wave vertical propagation in the westerly phase of QBO. Therefore, the presented report re-emphasizes the importance of QBO controlling the middle atmospheric dynamics through vertical propagation of planetary scale waves in low-latitudes.

doi : https://doi.org/10.1016/j.jastp.2019.105068

**(Kondapalli Niranjan Kumar, Som Kumar Sharma, and Vaidehi Joshi)**

**Vertical wavenumber spectral characteristics of temperature in the stratosphere-mesosphere over tropical and subtropical regions**

The vertical wavenumber spectra over tropical location, Gadanki (13.5°N, 79.2°E) and sub-tropical location, Mt. Abu (24.5°N, 72.7° E) is studied using the temperature measurements from ground based Rayleigh Lidar and space borne satellite observations. The slope values are lesser over Gadanki than at Mt. Abu for almost all the altitudes except for 40-50 km where it is nearly same and 60-70 km exhibiting opposite nature. Unusual spectral slope of 6.97 (Mt. Abu) and 0.09 (Gadanki) is seen at the altitude of 40-50 km in satellite temperature. Characteristics of wave oscillations perceived over both the stations are described.

doi : https://doi.org/10.1016/j.jastp.2019.05.017

**(Priyanka Ghosh and Som Sharma)**

**Investigation of vertical wavenumber spectra during sudden stratospheric warming (SSW) events over the Indian region**

The vertical wavenumber (VWN) characteristics during sudden stratospheric warming (SSW) events (2003-2016) is investigated for the first time using temperature observation of Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) on board Thermosphere Ionosphere Mesosphere Energetics Dynamics (TIMED) satellite (for the altitude range of 20-70 km) and ERA-Interim reanalysis data (for the altitudes of 0.1-20 km). Highly negative VWN spectral slope value (approximately) of -4.82 (at 25° N, 77° E) and -4.41 (at 35° N, 77° E) at 40-50 km altitude is observed during the 2013 SSW event, a sort of which is not perceived in any other SSW events (20032016). The combined effect of planetary waves (PWs) with wavenumber 1 and 2 during 2013 SSW may be responsible for such distinctive observation near the peak temperature altitude. This study elicits the importance of polar vortex portraying that lower latitudes are affected if only the vortex splits and presents the first of its kind VWN characteristics during SSW events.

doi : https://doi.org/10.1080/2150704X.2019.1601274

**(Priyanka Ghosh and Som Sharma)**

**Inter-comparison of INSAT-3D atmospheric motion vectors height with cloud-base height from a Ceilometer**

The atmospheric motion vectors (AMV) are derived by tracking cloud and moisture features in the subsequent images of geostationary as well as polar satellites. The heights of the AMVs are nothing but the height of cloud tracers used during the retrieval process for tracking. This height is derived using different complex techniques. In this study, a detailed comparison has been performed with the use of ground-based cloud-base height (CBH) measurements from ceilometer CL31, installed at Ahmedabad (23.03°N, 72.54°E), India and height assigned to AMVs which are retrieved from INSAT-3D satellite images. Six months CBH measurement over Ahmedabad from ceilometer CL31 has been used to inter-compare the co-located AMV heights. Although both ground based and satellite-based techniques have their own limitations, however, it is found from this study that the ceilometer is an excellent instrument to precisely detect low- and mid-level clouds and height-assignments technique of AMVs retrieved from INSAT3D satellite provides all high-, mid- and low-levels cloud information over this region. As an example, it is found that AMVs height of INSAT-3D is about 867, 750 and 465 hPa on 26 May 2014, 7 July 2014 and 29 October 2014, respectively, which matches very closely with ceilometer-measured CBH of about 873, 769 and 507 hPa, respectively. However, in case multi-level clouds present on rainy days, CBH measurements from ceilometer are differing from INSAT-3D AMV cloud tracer heights.

doi : https://doi.org/10.1080/01431161.2019.1698073

**(Som Kumar Sharma and S. Lal)**

**Investigation of solar cycle dependence of the tides in the low latitude MLT using meteor radar observations**

Solar cycle dependence of the dominant tides, i.e. diurnal and semidiurnal components in the mesosphere and lower thermosphere (MLT) is investigated from a Southern hemispheric low-latitude station, Cachoeira Paulista (22.7°S, 45°W) using long-term meteor wind observations (1999-2018).

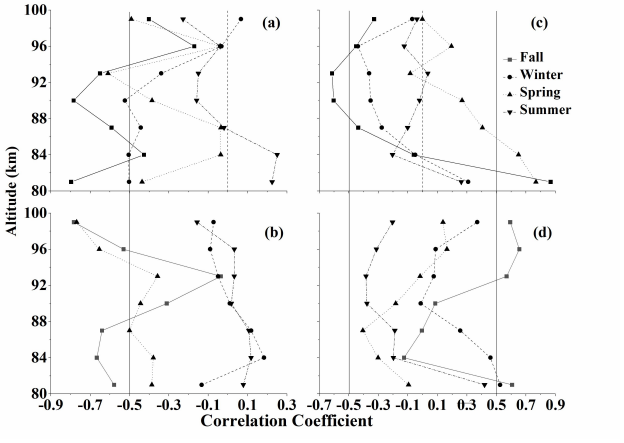


Figure no.6: Vertical profiles of the correlation coefficients for all seasons between the solar flux and (a) diurnal tide in the zonal wind, (b) diurnal tide in the meridional wind, (c) semidiurnal tide in the zonal wind and (d) semidiurnal tide in the meridional wind. The vertical solid and dashed lines denote $\pm 0.5$ and 0, respectively in the abscissa.

Although the long-term variations of the tides in aggregate do not show any significant relationship with the solar activity, the individual seasonal profiles reveal appreciable correlation in equinoxes with maximum in fall and no evident correlation in summer. The diurnal tide seasonal profiles show negative correlation with the solar activity and the semidiurnal tide exhibits both negative and positive correlations that vary with altitude within the MLT (Figure 6). The zonal diurnal tide shows positive correlation with the solar flux in the upper MLT in solar minima. However, the meridional semidiurnal tide reveals negative correlation in solar minima. No evident relationship between the tides and solar flux is found in solar maxima.

The research work was done in collaboration with a) P. P. Batista, National Institute for Space Research, São José dos Campos, São Paulo, Brazil b) V. F. Andrioli, State Key Laboratory of Space Weather, National Space Science Center, Chinese Academy of Sciences, Beijing, China.

doi : https://doi.org/10.1016/j.jastp.2019.105083

**(A. Guharay)**

**Study of solar cycle dependence of the quasi-two-day wave in the MLT from an extratropical station**

The relationship between the quasi-two-day wave (QTDW) and solar variability during summer in the MLT is studied using long-term meteor wind observations from an extratropical station, Cachoeira Paulista (22.7°S, 45°W) in the Southern hemisphere.

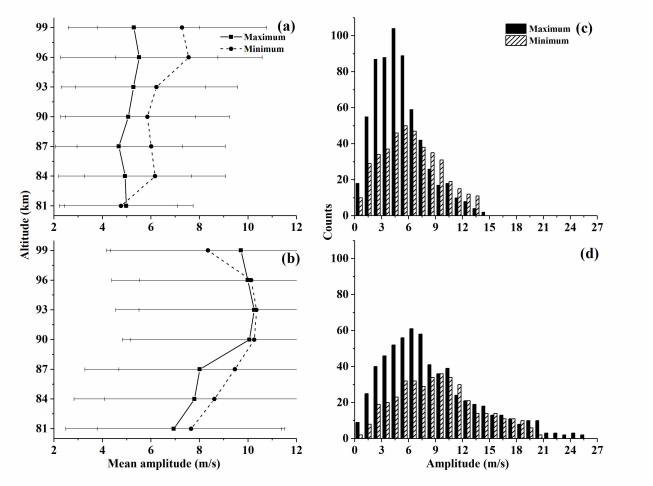


Figure no.7: Vertical profiles of the seasonal (summer) mean amplitude of the QTDW in solar extrema derived from (a) zonal, and (b) meridional components. The horizontal bars represent the standard deviation. Occurrence rate of the wave amplitude in solar extrema obtained from (c) zonal and (d) meridional components.

Overall, the seasonal (summer) mean and monthly mean zonal amplitude of the QTDW shows a negative correlation and the meridional amplitude exhibits a positive correlation with the solar F10.7 flux in the MLT. Although the seasonal mean (summer) wave period shows positive correlation with the solar cycle, both positive and negative correlations are found in the monthly mean period in certain summer months at the present location. Additionally, both amplitude and period of the QTDW show slightly higher values in solar minimum and lower values in solar maximum within the limit of standard deviation indicating a weak but measurable response to the solar cycle (Figure 7).

The research work was done in collaboration with a) P. P. Batista, National Institute for Space Research, São José dos Campos, São Paulo, Brazil b) V. F. Andrioli, State Key Laboratory of Space Weather, National Space Science Center, Chinese Academy of Sciences, Beijing, China.

doi : https://doi.org/10.1007/s12040-019-1316-1

**(A. Guharay)**

**Role of long-lived Kelvin-Helmholtz billows in generating the long-lasting "C-type" structures in the sodium lidargram**

In order to understand the characteristics of long-lasting "C-type" structure in the Sodium (Na) lidargram, six cases from different observational locations have been analyzed. The Na lidargram, collected from low-, middle-, and high-latitude sites, show long lifetime of the C-type structures which is believed to be the manifestation of Kelvin-Helmholtz (KH) billows in the Mesosphere and Lower Thermosphere (MLT) region. The long life time of these KH billows is counter-intuitive and called for detailed investigation. The Brunt-Vaisala frequency derived using the temperature profiles obtained from the Na lidars and the SABER measurements onboard TIMED satellite is found to be positive in the regions where C-type structures are found for all the six cases. This indicates that the regions were convectively stable. Based on simultaneous wind measurements, the Richardson numbers and Reynolds numbers for three cases are calculated. These calculations suggest that the regions where the C-type structure appeared were dynamically stable and non-turbulent. It is suggested that low temperature can increase the magnitude of the Prandtl number and convectively stable atmospheric region can cause the magnitude of Reynolds number to decrease. As a consequence, the remnant of previously generated KH billows, in nearly frozen-in condition, can advect through this conducive region to a different location by the background wind. This result suggest that under favorable conditions the lifetime of KH billows can increase and these billows can sustain for a long time without much deformation. These long-lived KH billows in the MLT region can eventually manifest the long-lasting C-type structures in the Na lidargram.

This work is done in collaboration with S. Mondal, S. Sarkhel, J. Agarwal [IIT-Roorkee]; Tao Yua and X.Cai [USU, UT, USA]; A. Liu [Embry-Riddle Aeronautical University, FL, USA]; S. Nozawa, [Nagoya University, Japan]; N. Saito [RIKEN Center for Advanced Photonics, Wako, Japan]; T. Kawahara [Shinshu University, Japan]; M. G. Mlynczak [NASA Langley Research Center, VA, USA] and J. M. Russell III [Hampton University, VA, USA].

doi : https://doi.org/10.1029/2019JA026630

**(D. Chakrabarty and R. Sekar)**

**Estimation of horizontal Gravity Waves scale sizes in the daytime thermosphere**

The importance of gravity waves (GW) in the dynamics of the upper atmosphere is well known. It has been shown that GW time periods, their vertical phase propagation speeds, and vertical scale sizes can be derived using digisonde measurements. Using these parameters, an attempt has been made to estimate the horizontal scale sizes of GWs. The GW dispersion relation used is given as follows:

$$m^2 = \frac{(k^2+l^2)(\mathrm{N}^2-\overline{\omega}^2)}{(\overline{\omega}^2-f^2)} - \frac{1}{4\mathrm{H}^2}$$

where, k, l, and m are the wave numbers in x, y (horizontal), and z (vertical) directions, respectively; N is the Brunt- Väisälä frequency; f = 2Ωsin$\phi$ is the Coriolis parameter (Ω is the Earth's rotation rate and $\phi$ is the latitude); $\overline{\omega}$ = $\omega$ - $\overrightarrow{k}.\overrightarrow{u} - \overrightarrow{l}.\overrightarrow{v}$), is the intrinsic GW frequency, that is, the frequency value if measured in the reference frame moving with the background wind ($\overrightarrow{u}$, zonal, and $\overrightarrow{v}$, meridional); $\omega$ is the GW frequency as observed from ground; and H is the neutral scale height.

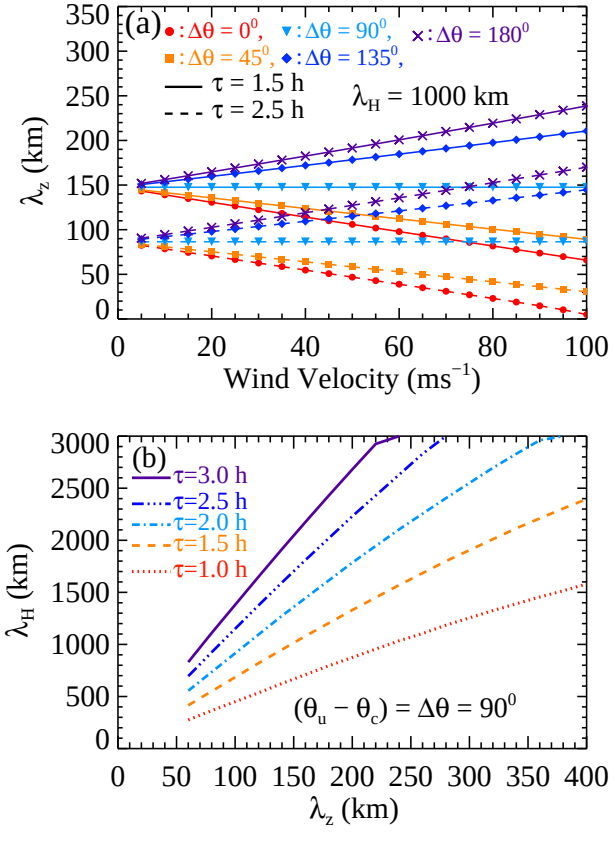


Figure no.8: (a) Simulation of gravity wave (GW) vertical scale sizes ($\lambda_z$) for horizontal scale size ($\lambda_H$) of 1,000 km using wind values ranging from 0 to 100 ms$^{-1}$ and the relative angles ( $\theta$= $\theta$u - $\theta$c) of 0°, 45°, 90°, 145°, and 180° between the direction of propagations of wave ($\theta$c) and wind ($\theta$u) for GW periods of 1.5 hr (solid lines) and 2.5 hr (dashed lines) obtained using GW dispersion relation. (b) Simulation of $\lambda_H$ obtained for range of values of $\lambda_z$, at $\theta$ = 90° for GW time periods in the range of 1 - 3 hr are shown to enable a first-order estimation of horizontal GW scale sizes in the absence of information on winds and GW propagation direction(s).

In the relation given above, we use vertical scale size ($\lambda_z = \frac{2\pi}{m}$) values derived through the radio method and model NRLMSIS-00 neutral atmosphere as inputs. Simulations are carried out to estimate the horizontal scale sizes ($\lambda_H$) for different vertical scale sizes ($\lambda_z$) for wind speeds (U) varying from 0 to 100 ms$^{-1}$. As the relative direction of winds with respect to that of propagation of GWs has a bearing on the GWs characteristics, several representative angles ($\Delta\theta$) ranging from 0° to 180° have been considered. The results for two different GW time periods (1.5 and 2.5 hr) are shown in Figure 8a as solid and dashed lines. If the ambient wind is in the same direction as the GW propagation ($\Delta\theta$ = 0°), then horizontal scale size grows at the expense of vertical scales. Conversely, if the wind in the opposite direction to GW propagation ($\Delta\theta$ = 180°), then the vertical scale size increases as the ambient wind speed increases. Thus, as $\Delta\theta$ increases form 0° to 180°, the same value of horizontal scale size of 1,000 km corresponds to higher values of vertical scale sizes. It may be noted that when the winds flow in orthogonal direction ($\Delta\theta$ = 90°) to that of the wave propagation, the magnitudes of ambient wind speeds do not have any effect on the vertical and horizontal scale sizes. Therefore, in the absence of knowledge of wind magnitudes and directions at those altitudes and limitation of information on the wave propagation direction, orthogonality in wind flows with respect to GW propagation direction ($\Delta\theta$ = 90°) can be considered to get an estimate of $\lambda_H$ values for the measured time periods and $\lambda_z$ values of GWs as shown in Figure 8b. The calculations are carried out for different GW time periods ranging from 1 to 3 hr and are presented in Figure 8b. The simulation results given in this figure can be considered to get a first-order estimate of the horizontal scale sizes of a GW, given its $\tau$ and $\lambda_z$. For example, from this figure, for $\tau \cong$ 2 hr and $\lambda_z$ of 300 km, $\lambda_H$ turns out to be ∼2,500 km, whereas for $\tau \cong$ 1.5 hr and $\lambda_z$ of 300 km, the value of $\lambda_H$ is ∼1,400 km.

doi : https://doi.org/10.1029/2019JA026723

**(Subir Mandal, Duggirala Pallamraju, Deepak Karan, Ravindra P. Singh and Pradip Suryawanshi)**

**Unusually large electric field perturbations in equatorial ionosphere due to the passage of two consecutive ICMEs during 6-8 September 2017 and its consequences**

Unusually large electric field disturbances in the dip-equatorial ionosphere were observed when two consecutive interplanetary coronal mass ejections (ICMEs) hit the terrestrial magnetosphere resulting in a strong geomagnetic storm during 6-8 September 2017. The magnitudes of these large electric field perturbations were not found to be consistent with the expected storm time penetration electric field magnitudes. In order to understand this aspect, a detailed investigation is carried out based on ionospheric observations from Peruvian (Jicamarca) and Asian sectors (Philippine) using vertical drifts and EEJ strength respectively along with the respective quiet time variations (see Figure 9). It is found that the first ICME sheath caused DP2 type of quasi-periodic prompt penetration (PP) electric field perturbations (with periodicities of 60 min and 45 min) for almost 10 hours in the equatorial ionosphere. The shock associated with the second ICME enhanced the F-region vertical plasma drift to ∼ 150 ms$^{-1}$ (Figure 9) in the evening hours over Jicamarca. This is one of the highest vertical drift ever measured over Jicamarca. The same PP electric field caused unusually large enhancement of the equatorial electrojet (EEJ) strength to ∼ 135 nT in the early morning

hours over the Philippine sector. The disturbance dynamo (DD) that followed the storm caused an upward vertical drift of $\sim$ 55 $ms^{-1}$ during post-midnight hours over Jicamarca which is also one of the highest observed. These unusually large electric field perturbations caused significant changes in the F region plasma fountain over low latitudes.

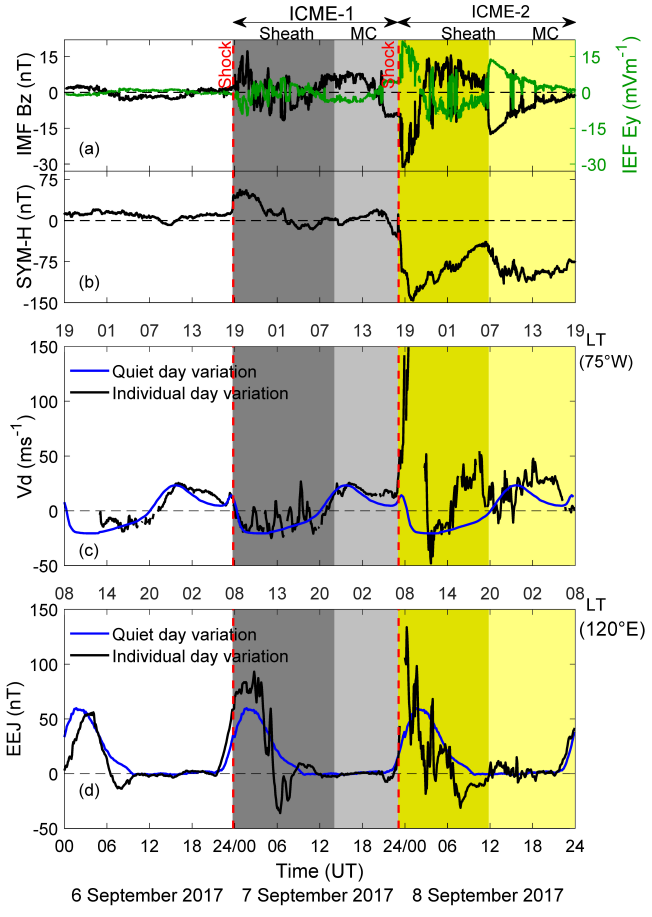


Figure no.9: Variations in (a) interplanetary magnetic field (north-south component, IMF Bz in nT) and electric field (dawn-dusk component, IEFy in mV$m^{-1}$) and (b) ring current strength (SYM-H, in nT) during the geomagnetic storm of 7-8 September 2017 driven by two interplanetary coronal mass ejection (ICME-1 and ICME-2) events (highlighted with gray and yellow color shades). The arrivals of the shock, sheath and magnetic cloud (MC) regions for both the ICMEs are marked in the figure. The ionosphere impact of this event is investigated based on ionospheric observations from Peruvian (Jicamarca) and Asian sectors (Philippine) using vertical drifts (in $ms^{-1}$, shown in (c)) and EEJ strength (nT, shown in (d)) respectively along with the respective quiet time variations (blue colored line). On 7th September, DP2 type periodic fluctuations are observed over both longitude sectors for about 10 hours owing to fluctuating IMF Bz. On 8th September, unusually large enhancements are observed in vertical drift over Jicamarca and EEJ over Philippine. The vertical drift increased to 150 m/s which is the largest recorded till date. Also, unusually large changes are observed in vertical drift during the recovery phase of the geomagnetic storm due to disturbance dynamo effect. The magnitudes of these electric field perturbations (both prompt and delayed) can be explained only if significant contributions from substorms (not shown in the Figure) are taken into account.

It is shown that the magnitudes of these electric field perturbations (both prompt and delayed) can be explained if significant contributions from substorms are taken into account. Therefore, this investigation shows that substorms can work in tandem with the storm-time electric field perturbations to generate anomalously high impact on the equatorial ionosphere. This work has implication for the evaluation of storm time plasma distribution over low latitudes.

This work is done in collaboration with Xian Lu [Clemson University, SC, USA].

doi : https://doi.org/10.1029/2019JA027133

**(D. Rout, K. Pandey, D. Chakrabarty and R. Sekar)**

**Observations of possible substorm related over-shielding electric field effects on equatorial ionosphere under steady southward IMF Bz condition during main phase of magnetic storm**

In general, the over-shielding effects associated with the Z-component (North-South) interplanetary magnetic field (IMF Bz) occurs when IMF Bz suddenly turns northward after being steadily southward for some time. This, in general, happens at the onset of the recovery phase of a geomagnetic storm. In this work, contrary to this existing notion, interesting observations of the strong westward electric field in the day side equatorial latitudes are presented, as evidenced by strong Counter Electrojet (CEJ) at Indian and Japanese sectors under the steady southward IMF Bz conditions. The westward electric field perturbations are quite large with CEJ amplitude of $\sim$ -120 nT over the Indian sector (14-15 December 2006) and $\sim$ -220 nT for Japanese sector (7-8 November 2004). The plausible mechanisms for the observed overshielding electric fields under steady southward IMF Bz have been investigated in light of the possible role of substorm activity. These observations support the recent modeling work that shows that substorm can create overshielding like scenario in the inner magnetosphere under steady southward IMF Bz condition during the main phase of geomagnetic storm.

This work is carried out in collaboration with B. Veenadhari and S. Tulasiram [IIG, India]; T. Kikuchi [Nagoya University, Japan]; Y. Ebihara [Kyoto University, Japan] and G. D. Reeves [LANL, NM, USA].

doi : https://doi.org/10.1016/j.asr.2019.04.001

**(Sandeep Kumar and D. Chakrabarty)**

**Three different episodes of prompt electric field perturbations on equatorial ionosphere during St. Patrick's Day storm**

Conventionally, prompt penetration electric field perturbations on equatorial ionosphere are associated with the southward or northward turnings of the Z-component (North-South) of interplanetary magnetic field (IMF Bz). However, in this investigation, it is shown that three different episodes of prompt penetration electric field (PPEF) disturbances occurred during the main phase of the St. Patrick's Day storm on 17 March 2015 under steady southward IMF Bz condition. These PPEF events took place during the period when strong disturbance dynamo fields were prevailing in the background. The first event was triggered by a solar wind dynamic pressure pulse that caused a sharp eastward PPEF and strong enhancement of equatorial electrojet current in Brazilian dayside. The second event caused another short but strong westward PPEF on dayside due to the reversal of IMF By from duskward to dawnward under steady IMF Bz. The third event caused a longer eastward PPEF in association with a solar wind dynamic pressure pulse followed by the onset of

a substorm which led to strong enhancement of equatorial electrojet, quick rejuvenation and symmetric redistribution of equatorial ionization anomaly in the Brazilian sector. The signatures of the PPEF with opposite polarity and smaller magnitudes are also observed in the Asian sector on the nightside. This investigation highlights the need to understand the PPEF disturbances phenomenologically to gauge the equatorial impact in a better way.

This work is done in collaboration with S. Tulasi Ram, B. Nilam and B. Veenadhari [IIG, India]; N. Balan, Q. Zhang and Z. Xing [Shandong University, China]; K. Shiokawa [Nagoya University, Japan]; K. Venkatesh [NARL, India]; and A. Yoshikawa [Kyushu University, Japan].

doi : https://doi.org/10.1029/2019JA027069

**(D. Chakrabarty)**

**CDAP (CCD-based Daytime Airglow Photometer)**

A new technique to obtain daytime optical emissions has been developed. This technique uses a fixed airgap Fabry Perot etalon as a high spectral resolution filter, a low-resolution filter and a charged coupled device (CCD) detector to arrive at a new means to detect the OI 630.0nm dayglow line emission rates in the presence of strong scattered daytime background continuum. The optical layout is shown in Figure 10.

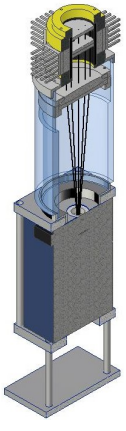

Figure no. 10: Cross-section of CDAP (CCD-based Daytime Airglow Photometer)

The incident sky light that passes through the aperture is isolated by an interference filter in the range of $\pm$ 0.15 nm centred at 630.0 nm. Light thus isolated is passed through the Fabry Perot etalon to produce interference fringes as shown in Figure 11. This image also shows the spectral lines superposed on it wherein the wavelength of Fraunhofer absorption lines have been identified. Also shown is the OI 630.0nm spectral region at which emissions occur. The CCD has been programmed to obtain images as a function of local time in an automated fashion at pre-set integration times. From such images the spectral regions of the signal and its neighbouring background regions are identified through the analysis software for every image and the integrated counts so obtained in these two regions are subtracted to yield the signal values alone. This CDAP has been commissioned at the newly initiated Optical Aeronomy Observatory in the PRL's Thaltej campus. Initial calibration and quantification tests of CDAP are underway. Once the tests are completed this new technique, which is portable, automated, rugged, and has no moving parts will be ready for commissioning for field operations.

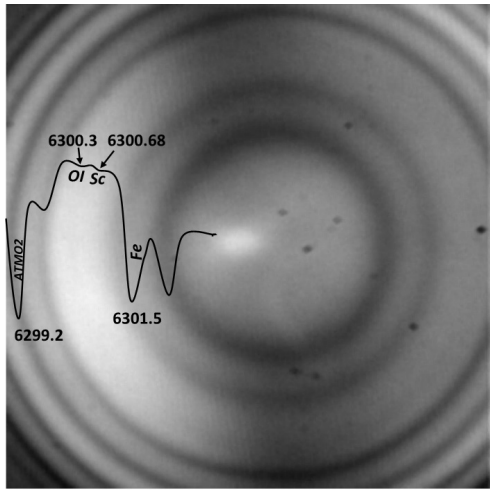


Figure 11 : The image obtained by CDAP. Dark, Fraunhofer, absorption lines that are seen are identified as those due to Fe, OI and Scandium. The OI regions consists of the dayglow emissions as well, in addition to the background scattered contribution.

**(Duggirala Pallamraju, Pradip Suryawanshi, Shashank Urmalia, Sovan Saha, Sunil Kumar, and Ravindra Pratap Singh)**

**Software for derivation of mesospheric temperatures using OH(3-1) band emission**

Nocturnal OH(3-1) emission band spectra is being measured using PRL Air-glow Infrared Spectrograph (PAIRS) from optical aeronomy observatory, PRL Thaltej campus.

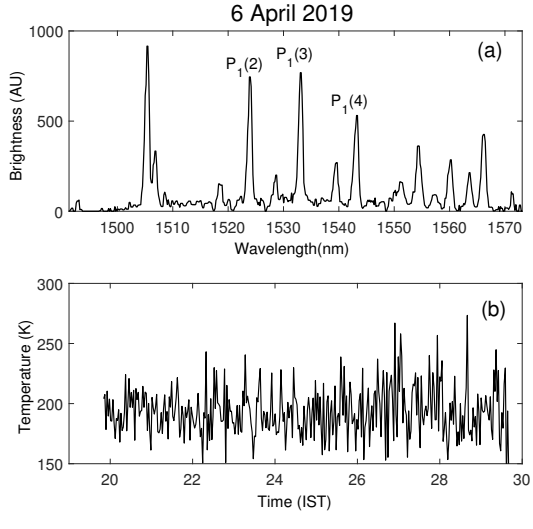


Figure no. 12: (a) Nightglow spectrum obtained from PAIRS. OH(3-1) band $P_1(2)$ and $P_1(4)$ rotational lines at 1523.7 nm and 1542.8 nm, respectively has been used for the derivation of temperatures corresponding to 87 km altitude. (b) Nocturnal variations in corresponding rotational temperature.

The rotational levels of OH band emission are sensitive to the ambient temperatures which are used to derive the temperatures of the OH emission altitude ($\sim$87 km). PAIRS use InGaAs photo-diode arrays which are known for high dark current. An automated data analysis tool has been developed to derive night-glow emission intensities of different rotational lines of OH(3-1) band from which corresponding temperatures have been obtained. A sample spectrum is shown in Figure 12(a) and nocturnal variation in the derived temperature for the night of 6 April 2019 in Figure 12(b).

**(Ravindra P. Singh and D. Pallamraju)**

# Geosciences

**Palaeohydrology of the river Ghaggar**

The legendary river Saraswati of Indian mythology has often been hypothesized to be an ancient perennial channel of the seasonal river Ghaggar that flowed through the heartland of the Bronze Age Harappan civilization in north-western India. Despite the discovery of abundant settlements along a major paleo-channel of the Ghaggar, many believed that the Harappans depended solely on monsoonal rains, because no proof existed for the river's uninterrupted flow during the zenith of the civilization. Here, we present unequivocal evidence for the Ghaggar's perennial past by studying temporal changes of sediment provenance along a 300 km stretch of the river basin. This is achieved using $^{40}$Ar/$^{39}$Ar ages of detrital muscovite and Sr-Nd isotopic ratios of siliciclastic sediment in fluvial sequences, dated by radiocarbon and luminescence methods. We establish that during 80-20 ka and 9-4.5 ka the river was perennial and was receiving sediments from the Higher and Lesser Himalayas. The latter phase can be attributed to the reactivation of the river by the distributaries of the Sutlej. This revived perennial condition of the Ghaggar, which can be correlated with the Saraswati, likely facilitated development of the early Harappan settlements along its banks. The timing of the eventual decline of the river, which led to the collapse of the civilization, approximately coincides with the commencement of the Meghalayan Stage.

doi : https://doi.org/10.1038/s41598-019-53489-4

**(A. Chatterjee, A.D. Shukla and J.S. Ray)**

**Provenance of siliciclastic sediments in the Andaman forearc basin**

The Himalayan orogeny has been recognized as one of the most important Cenozoic events that shaped the geography, climate and ocean chemistry of our planet. The erosion in the Himalayas is believed to have played a critical role in crustal deformation and changes in the chemistry of the ocean water since the Eocene. In spite of the fact that the orogeny began after India - Asia collision at 59$\pm$1 Ma, the record of its earliest erosional history is meagre. In an attempt to fill this gap in the knowledge, we studied temporal changes in provenance of Paleogene–Neogene siliciclastic sediments of the Andaman Islands, deposited in a trench-forearc basin in the Bay of Bengal. Using Sr-isotope stratigraphy and tephrochronology we determined the timings of depositions of various lithologies. Sediment sources were identified using trace element and isotopic (Sr-Nd) fingerprinting. Results of our study suggest that the Myanmar Arc had remained a constant sediment source to the Andaman basin during 55 – 5 Ma, whereas the basin started receiving significant continental sands input after 35 Ma that increased with time until $\sim$20 Ma. Geochemical provenance of these sands suggests their derivation from Precambrian crustal sources in the Himalaya, which probably is an outcome of higher erosional rates subsequent to a rapid exhumation of the orogen in the late Eocene and efficient sediment transport through the palaeo-channels of the rivers Brahmaputra and Ganga under optimal conditions of the Indian monsoon. Such a scenario is consistent with the idea that the Himalayan sediment input is the cause for the conspicuous rise in marine $^{87}$Sr/$^{86}$Sr since $\sim$40 Ma. Our data also suggest that since the Miocene, sediment sources in the Indo-Burman Ranges and the Myanmar arc have become the major contributors to the Andaman Basin through the Irrawaddy river system.

doi : https://doi.org/10.1007/s12040-019-1266-7

**(N. Awasthi and J.S. Ray)**

**Depositional history of the Proterozoic Chhattisgarh Basin**

The Chhattisgarh Basin is one of the most important Proterozoic basins of peninsular India. Owing to its deposition in the Mesoproterozoic, the largely undeformed and unmetamorphosed sedimentary sequence of this basin is believed to hold vital clues to our understanding of the evolution of the Indian craton subsequent to the disintegration of the supercontinent Columbia. Despite its importance, only limited studies have been carried out to decipher the depositional history of the basin and to correlate various litho-units in it. Here, we present results of quantitative provenance analysis of the sediments in the basin using trace element and Nd isotopic ratios and discuss their implications for the evolution of the basin in the context of regional tectonics. The sediment provenance analysis reveals that the spatially extensive $\sim$2.5 Ga old granitoids of the Bastar craton were the major contributors (45% to 65%) of the total sediment budget into the basin during its initial stage of evolution. As sedimentation progressed the contribution from the Bastar granitoids was restricted to less than 30% of the total budget with the remaining supplied by younger 1.6 - 1.7 Ga magmatic rocks. The overall provenance of sediments appears to have remained constant throughout the evolutionary history of the basin; however, the relative contributions of various sources did change with time. The latter is highly conspicuous across the stratigraphic boundary between the Singhora and Chandarpur groups, in the lower part of the Chhattisgarh Supergroup. The geochemical data suggest that the basin developed as a result of either rift or sag

into which the sea incursion occurred through the adjacent grabens during the Mesoproterozoic marine transgression.

doi : https://doi.org/10.1080/00206814.2020.1712557

**(B.G. George and J.S. Ray)**

**Hydrometeorological processes in semi-arid western India: Insights from long term isotope record of daily precipitation**

Long term (2005-2016) daily precipitation isotope data ($\delta^{18}$O, $\delta$D and d-excess) from Ahmedabad in semi-arid Western India have been examined in light of various meteorological parameters and air parcel trajectories to identify prominent patterns in the isotopic character and to discern the underlying hydrometeorological processes. One of the most prominent and systematic annual pattern is the isotopic depletion (average $\delta^{18}$O : - 2.5‰in Jun-Jul; -5.2‰in Aug-Sept) in the second half of the Indian Summer Monsoon (ISM), which is observed in the 11 out of the 12 years of this study. Four geographically feasible causal factors have been examined if they contribute to observed late monsoon isotopic depletion. These factors are: (1) increased contribution of terrestrially recycled vapor; (2) intra-seasonal change in sea-surface, surface-air and cloud base temperatures; (3) increased rain-out fraction from marine vapor parcel; and (4) increase in relative proportion of convective rain.

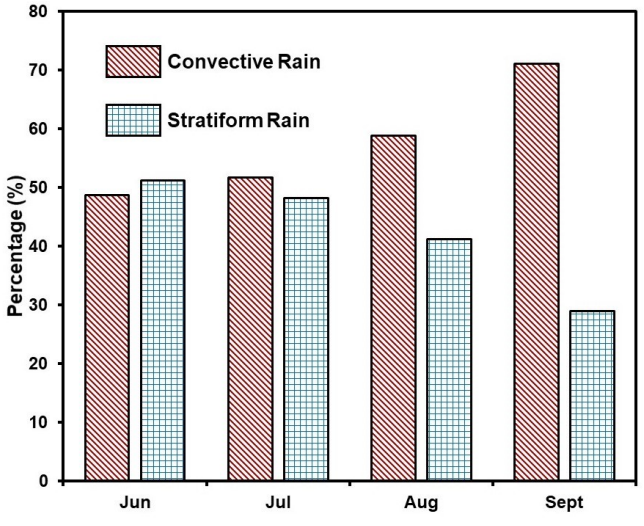


Figure No.1: Monthly proportion of rain derived from convective and stratiform clouds at Ahmedabad during ISM computed based on TRMM data for 16 years (1998-2013).

It is inferred from the present study that isotopic depletion in the second half of ISM is associated with: (i) increased contribution (from 36% to 45%) of terrestrially recycled moisture; (ii) 1.9$^{\circ}$C lower cloud base temperature; (iii) increased rainout fraction due to decreased wind velocity (from 8.8 m/s to 6.9 m/s); and (iv) a small (7%) increase in the proportion of convective rain. Daily rain events with atypical isotopic composition (20‰$<$ d-excess $<$ 0‰) are ascribed mainly to local weather perturbations causing sudden updraft of moist air facilitating terrestrial recycling of water vapour.

*This work is done in collaboration with Dr. T. N. Rao, National Atmospheric Research Laboratory (NARL), Gadanki.*

doi : https://doi.org/10.1007/s00382-020-05136-2

**(H. Oza, V. Padhya, A. Ganguly & R.D. Deshpande)**

**Hydrochemical assessment (major ions and Hg) of meltwater in high altitude glacierized Himalayan catchment**

With a view to understand the hydrochemical and isotopic characteristics and the source of Hg contamination in high altitude glacierized Himalayan catchment, the samples of snowpack and glacial melt were collected. Both the snow and glacial melt were acidic in nature with calcium and magnesium as the dominant cations, and bicarbonate and chloride as the dominant anions. The major ion concentrations for cations were found to be $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ and $HCO_3^{-} > Cl^{-} > SO_4^{2-} > NO_3^{-}$ for anions. The atmospheric processes like the precipitation source and aerosol scavenging control the snow chemistry and the weathering of the rocks modify the hydrochemistry of glacial melt. The samples of both the snow and glacial melt were classified as Ca-Mg-$HCO_3^{-}$ type. The concentration of Hg in snow (154.95 ng $L^{-1}$) and glacial melt (112.04 ng $L^{-1}$) was highest during summer season (August–September) and lowest (snow 2.2 and 40.01 ng $L^{-1}$ for glacial melt) during winter (November). However, the highest observed concentration of Hg in snow is lower compared to the maximum permissible limit of 1000 ng $L^{-1}$ set by WHO for drinking water. The results revealed that mercury concentration in snowpacks is attributable to the combined mixing of long-range transport of pollutants via westerlies throughout the year and the industrial effluents coming from highly industrial belts of Panjab, Haryana, Rajasthan, Indo-Gangetic plains, and neighbouring areas via southwest monsoons during August–September. However, in glacial melt, the Hg concentration was typically controlled by rate of melting, leaching, and percolation. Higher degree and rate of glacial melting decreases the Hg concentration in glacial melt. Stable isotopic analysis and backward air mass trajectory modeling also corroborate the source of precipitation from southwest monsoons during August–September, with its air mass trajectories passing through the highly industrialized belts of Indo-Gangetic plain and adjoining areas.

*This work was done in collaboration with Dr. Gh. Jeelani, University of Kashmir and his team.*

doi : https://doi.org/10.1007/s10661-019-7338-y

**(R.D. Deshpande)**

**Stable isotope ($\delta^{18}$O and $\delta$D) dynamics of precipitation in a high altitude Himalayan cold desert and its surroundings in Indus river basin, Ladakh**

To investigate the source, transportation, admixture of vapor sources and post-precipitation modification of stable water isotopic composition ($\delta^{18}$O and $\delta$D) of precipitation in the high-altitude Himalayan cold desert of Ladakh, upper Indus river basin (IRB) an observational network was established. Water resources in the

northwestern Himalayas are influenced by the circulation of two dominant weather systems: westerlies and southwest monsoons. The effect of climate change has significantly influenced the overall behaviour of these precipitation bearing climate systems and therefore, the meteorology of the region. Monthly composite (n = 110) and event wise precipitation samples (n = 32) were collected during the year 2015-16 for stable water isotopes ($\delta^{18}$O and $\delta$D). The stable water isotopic values of the precipitation samples were lower at higher altitude and in January. The monthly $\delta^{18}$O (and $\delta$D) of precipitation showed a negative correlation with altitude ($R^2$ = 0.93, p = 0.001) and temperature ($R^2$ = 0.71, p = 0.007). However, it was observed that the stable water isotopic value of precipitation abruptly drops at all the precipitation sites in August, without considerable variation in the ambient temperature and precipitation amount signifying the alteration in moisture source. The NCEP/NCAR reanalysis and back trajectory modelling also corroborates and suggests the modification in the moisture source and reversal of wind pattern during this period. The smaller d-excess values and lower slope (7.4) of local meteoric waterline than the global, regional and local meteoric water lines of western Himalayan, central Himalayas and Kashmir Himalayas indicate the secondary evaporation of falling raindrops below the cloud base. Lagrangian moisture diagnostic was used to recognize the sources, which endorsed the quantitative distinction of different evaporative moisture sources.

*This work was done in collaboration with Dr. Gh. Jeelani, University of Kashmir and his team.*

doi : https://doi.org/10.1016/j.atmosres.2019.01.025

**(R.D. Deshpande)**

**Graphitization System**

For radiocarbon dating, Accelerator Mass Spectrometer (AMS) based method requires sample carbon to be converted into graphite. In order to produce graphite, oxidation methods are adopted.

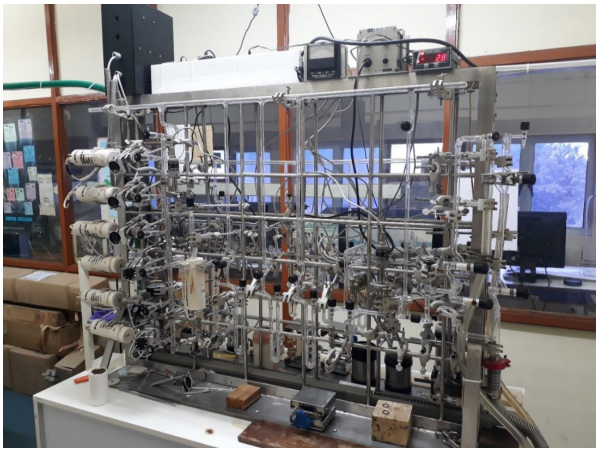

Figure No. 2: Glass system to extract carbon dioxide from milligram size carbon samples.

A vacuum glass system for the preparation of carbon dioxide from milligram size organic and inorganic samples has been developed in the radiocarbon dating laboratory of the geoscience division this year. Since for small size samples, chemical constituents such as sulphar and halides are the prime culprits responsible in spoiling subsequent graphite reactions, specific protocols have been developed to remove these at the combustion stage. The system developed has provision to load six samples at a time and carryout combustion one after another. Variety of materials viz. lake sediments, charcoal and peat have been processed succesfully. The system can also extract carbon dioxide from inorganic type carbon samples.

**(M. Shah and M.G. Yadava)**

**Laboratory development for chemical processing and measurement of meteoric $^{10}$Be using PRL- AMS**

With a long half-life of 1.36 Ma, $^{10}$Be can be used in understanding various earth science processes as well as dating quaternary events. Laboratory protocol was developed for extraction of beryllium from samples. The samples from a sediment core collected from the Indian Ocean were processed along with blanks and standards to check the efficiency of sample processing and measurements of meteoric beryllium-10. The sediment samples were powdered and leached using hydroxylamine hydrochloride solution in diluted acetic acid. The sample solutions were passed through anion column to remove iron from the solution and further though cation column to separate beryllium from the other ions. Subsequently, the pH of the solutions was changed from acidic to basic for beryllium to precipitate as $Be(OH)_2$. Samples were then combusted to form BeO at high temperatures. Finally, BeO was Mixed with Nb powder in a 1:2 ratio and was pressed in aluminium cathodes.

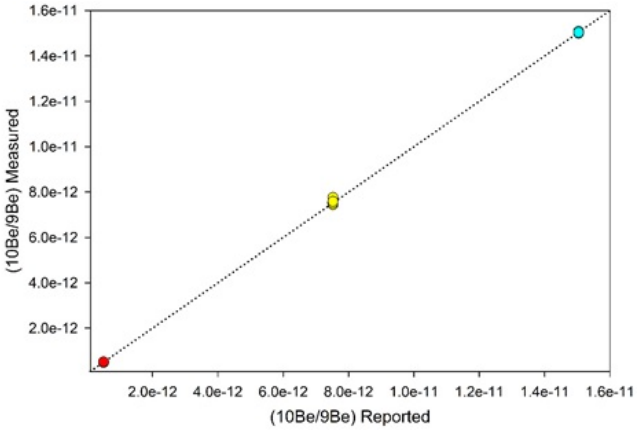


Figure No. 3: A plot showing comparison between the measured and consensus value of check standards. All the measured standards were well within 3% of the reported value.

Blanks and standards, along with Samples, were measured for the $^{10}$Be/$^{9}$Be ratio in PRL Accelerator Mass Spectrometer (AURiS) with measurement precision for individual standard targets within 3%. Total three types of standards with a $^{10}$Be/$^{9}$Be ratio ranging from $5.02\times10^{-13}$ to $1.504\times10^{-11}$ were measured, and the measured values were within 3% of the consensus value. In beryllium-10 measurement, the process blank value is very crucial with very low $^{10}$Be concentration.In our measurements, the process blank (1.05 $\times$

$10^{-14}$) was very much lower compared to the measured samples (5.79 - 9.25 $\times$ $10^{-12}$). The results show routine preparation and measurement of meteoric beryllium-10 can be performed in the laboratory. Further development of protocols is being made for extraction, and isotopic measurement of in-situ produced beryllium in the near future for various kind of samples for their application in earth sciences.

**(P. S. Jena, A. Shivam & R . Bhushan)**

**Signatures of global climatic events and forcing factors for the last two millennia from the active mudflats of Rohisa, southern Saurashtra, Gujarat, western India**

The limited extent of instrumental records going back in time and control of various climatic variables on Indian Summer Monsoon (ISM) has reinvigorated the unprecedented effort in documenting climate changes for the last two millennia. Although extensive studies on late Holocene ISM reconstruction are available, comprehensive understanding on the influence of natural forcing factors on ISM and their plausible signatures is not arrived at till date.

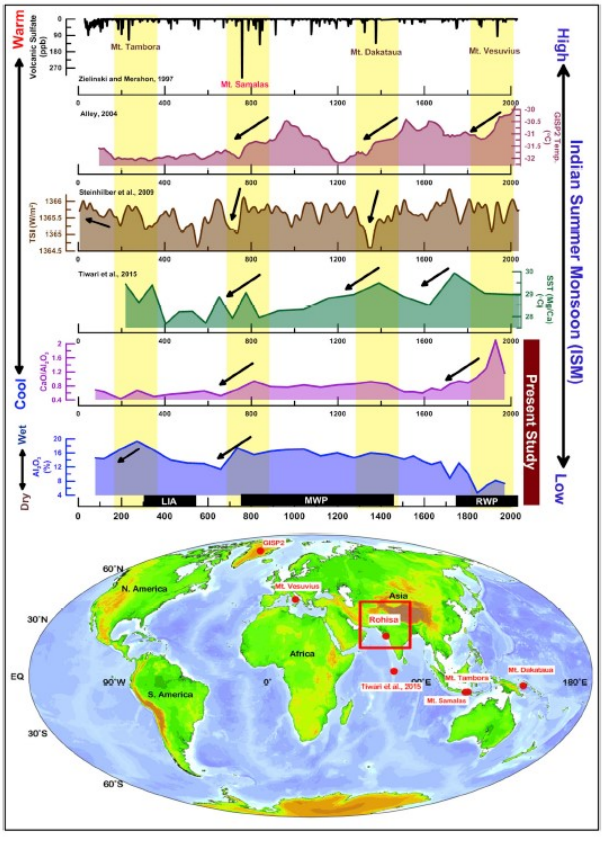


Figure No.4: Comparison of Rohisa sediment core proxies with contemporary global paleoclimate records (volcanic, TSI forcing, SST) for the last two millennia. Vertical yellow bands represent volcanic eruptions and its impacts on climate as indicated by various proxy studies. Mt. Samalas eruption has been found to be the most severe eruption during last two millennia which might led to onset of LIA.

In view of this, the present study attempts to address the ISM variations during the last two millennia with special emphasis on natural forcing factors (solar and volcanic) and climate variables (ocean-atmospheric processes).The Saurashtra peninsula of Gujarat in western India receives majority of rainfall during ISM and hence it provides an ideal test-bed to study the ISM variability. A multiproxy approach has been adopted on a sediment core retrieved from the active mudflat of Southern Saurashtra which was chronologically supported by $^{210}$Pb, $^{137}$Cs and $^{14}$C. The present study demonstrates vacillating climate with strengthened ISM during Roman Warm Period and Medieval Warm Period (2000-950 cal yr BP) as a result of increased solar irradiance interrupted by reduced ISM during Dark Ages of Cold Period ($\sim$1500 cal yr BP). The plausible occurrence of volcanic eruption before the onset of Little Ice Age (500 - 200 cal yr BP) caused the southward migration of Intertropical Convergence Zone (ITCZ) leading to enhanced western disturbances in the study area thereby resulting in cool and wet climate in the region. The study emphasizes the increased El Nino events with gradual decline in the ISM since Little Ice Age. Further, the study underscores a climate warming during the last two centuries that corroborates well with the instrumental records. Thus, the present study has implication towards understanding the significant role of volcanic activity and solar variability in controlling the millennia scale climate oscillations with additional feedback mechanisms.

*This work was done in collaboration with Dr. Upasana Baneerji, NCESS, Trivandrum and Prof. A.J.T. Jull from NSF-AMS Facility, University of Arizona, USA.*

doi : https://doi.org/10.1016/j.quaint.2019.02.015

**(R. Bhushan)**

**Measurement of Sr/Ca in Corals using ICP-OES**

Corals are unique natural archives which provide high resolution records of suites of proxies giving information about past climatic changes. Continuously growing hard skeleton of corals allows us to retrieve proxy records at monthly or seasonal resolution. In absence of instrumental records such proxy information become crucial for understanding the natural processes better. Coral Sr/Ca ratios has widely been used to study past SST (sea surface temperature) variations. Oxygen isotopic ratios in ($\delta^{18}$O) corals can be studied to reconstruct past SST. But, unlike $\delta^{18}$O in corals, Sr/Ca is not affected by parameters other than SST and Sr/Ca of seawater mostly remain stable. Thus, coral Sr/Ca ratios are often preferred over $\delta^{18}$O as proxy for SST. Studies based on Sr/Ca ratio of corals from Indian region are very scarce. Here, first coral Sr/Ca ratio based measurements from Andaman Islands is carried out. The coral samples were analysed for its Sr/Ca ratio using Theromofisher ICP-OES. The analytical precision for Sr/Ca analysis was 0.25% RSD or 0.02 mmol/mol ($1\sigma$). The Sr/Ca ratio in the Landfall coral samples ranges from 8.78 to 9.11 mmol/mol with mean value of 8.95 $\pm$ 0.07 mmol/mol. The study demonstrates a good correlation between Sr/Ca and SST values. Following correlation was obtained between coral Sr/Ca and SST of Andaman region,

Sr/Ca=(-0.06)$\times$SST + 10.59 ($R^2$ = 0.72; p$<$0.001)

The obtained equation is similar to the Sr/Ca–SST calibration reported for Porites around the globe.Such calibrations of proxy records are very useful for paleoclimatic reconstruction purpose.

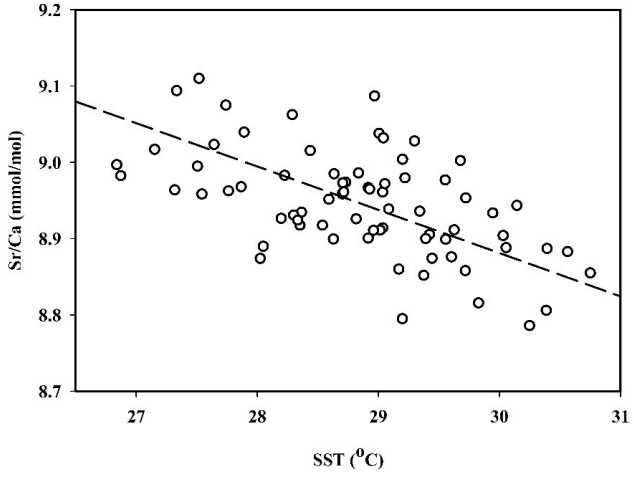


Figure No. 5: Correlation between Landfall Porites Sr/Ca ratio and Sea surface temperature (SST) values

**(H. Raj, R. Bhushan & A.K. Sudheer)**

**Radiocarbon Analysis of Groundwater samples from Indo-Gangetic Plain**

Radiocarbon age of groundwater provides information about the source, mixing and the time of recharge of aquifers. Using PRL AMS facility (AURiS), first attempt to date groundwater samples was carried out on samples provided by National Institute of Isotope Hydrology (originally from Ministry of Water resources) for study of water quality and isotopic measurements. This study pertained to examine groundwater flow in complex hydrological conditions e.g. groundwater flow in multi-aquifer systems in Indo-Gangetic plains. The samples were collected from deep water wells along the Indo-Gangetic Plain. Since the samples were older (tritium content $<$0.8 TU) and thus suitable for radiocarbon dating. Towards this, a suitable protocol was developed for processing of the samples for measurement using AMS. The samples supplied in the form of $BaCO_3$ (dissolved carbonate precipitated as $BaCO_3$) were processed in Carbonate Handling system (CHS: hydrolysis with 85% $H_3PO_4$ acid) and graphitized in AGE3. The graphitised samples were measured in AMS. The groundwater radiocarbon ages ranged from 3910 to 14885 years showing the recharge time of respective aquifers.

Radiocarbon ages for few ground water samples are as follows:

| AMS ID | Sample ID & Site | Age T (libby) | $\sigma$(T) |
|---|---|---|---|
| AURIS-00665 | WS-1-1 PAWNI KALAN | 7680 | 100 |
| AURIS-00666 | WS-2-1 ISHAGARH | 14885 | 190 |
| AURIS-00667 | WS-4-1 KAIKCOR | 6220 | 160 |
| AURIS-00668 | WS-6-1 BETA | 3910 | 105 |
| AURIS-00669 | WS-7-1 UNCHA CHANDNA | 10075 | 120 |

*This work was done in collaboration with Dr. Someshwar Rao, NIH, Roorkee.*

**(R. Bhushan, A. Dabhi & A. Shivam)**

**AMS Radiocarbon dating of Archaeological samples from Dholavira to study evolution of Harappan Civilization**

Radiocarbon dating of archaeological carbonates from seven cultural stages of Dholavira, Great Rann of Kachchh (GRK), the largest excavated Harappan settlement in India. Towards this, several carbonate samples (Moluscan/Otolith,Trerbralia & shell bangle) from seven cultural stages (I to VII) of Dholavira, Great Rann of Kutchch, Gujarat were processed for graphitisation using Carbonate Handling System (CHS) by Acid Hydrolysis method and finally graphitised in AGE3. Radiocarbon measurements of graphitised samples were done with PRL-AMS (AURiS). AMS radiocarbon age of several sample from Dholavira suggests beginning of occupation at $\sim$5500 years BP (pre-Harappan), and continuation until $\sim$3800 years BP (early part of the Late Harappan period). The Dholavira settlement flourished under favourable monsoonal climate conditions. The humid fluvial landscape possibly changed due to a catastrophic drought driving the final collapse of the settlement of Dholavira exactly at the onset of the Meghalayan (Late Holocene) stage ($\sim$4300–4100 years BP). Dholavira presents a classic case for understanding how climate change can increase future drought risk as predicted by the IPCC working group.

Table: Radiocarbon age of the relevant Harrapan Period and their cultural stages.

| Dholavira Cultural Stage | RadioCarbon Age Range(2$\sigma$, cal yeasr BP) | Harappan Period |
|---|---|---|
| VII | Younger than 3827 | Late to post-urban (?) Harappan |
| VI | 4138-3827 | Late Mature Harappan to Early Late Harappan |
| V | 4157-3980 | Late Mature Harappan |
| IV | 4840-3919 | Late Early Harappan to Late Mature Harappan |
| III | 4625-4585 | Transitional phase, Late Early Harappan to Early Mature Harappan |
| II | 4958-4332 | Transitional phase, Early to Mature Harappan(Dholavira culture) |
| I | 5491-4958 | Pre- to Early Harappan (Dholavira culture) |

*This work was done in collaboration with Prof. A. Sarkar, IIT, Kharagpur and his team*

doi : https://doi.org/10.1002/jqs.3178

**(R. Bhushan, A. Dabhi & H. Raj)**

**Reactive oxygen species generation capacity of atmospheric $PM_{10}$ over the marine atmospheric boundary layer**

Even though some of the micro-nutrients, such as redox-active trace metals, are important in regulating the primary productivity in the aquatic system, they are shown to be toxic for biota. For example, the production of higher levels of reactive oxygen species (ROS) in ocean waters via transfer of an electron from biological cells to

molecular oxygen through the catalytic activity of redox-active species. Atmospheric deposition is the major source of the redox-active species over remote oceans, and their capacity to generate ROS is known as their oxidative potential (OP). ROS are highly reactive form of oxygen, and are ubiquitous in the ocean surface water that may influence the marine biogeochemistry. Therefore, it is important to contemplate the OP of atmospheric aerosols over the marine environments. Continental outflow from South Asia and the Arabian Desert to the Arabian Sea is conspicuous characteristic during pre-monsoon months.

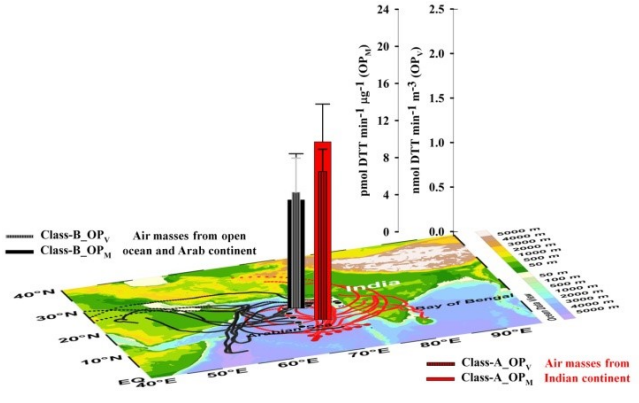


Figure No. 6: Volume-normalized (OPv) and mass normalized (OPM) oxidative potential of ambient $PM_{10}$ over the Arabian Sea under the influence of different air masses.

In the present study, $PM_{10}$ (particulate matter with aerodynamic diameter ⩽10 $\mu$m) samples were collected onboard over the Arabian Sea during April-May (i.e., pre-monsoon), 2017, and analyzed for a variety of chemical species. Dithiothreitol (DTT) assay was utilized to measure the OP of $PM_{10}$ for the first time over the marine environment in the world. $PM_{10}$ mass concentration, volume-normalized OP (represented as nmol DTT min$^{-1}$ m$^{-3}$ or $OP_V$) and mass-normalized OP (represented as pmol DTT min$^{-1}$ $\mu$g$^{-1}$ or $OP_M$) over the study region varied from 61 to 184 g m$^{-3}$, 0.69 to 2.08 nmol DTT min$^{-1}$ m$^{-3}$ and 6 to 26 pmol DTT min$^{-1}$ $\mu$g$^{-1}$, respectively. Further, the study period was classified into two categories (Class-A and Class-B) based on five-day air mass back trajectories for each sampling location. Average $OP_V$ and $OP_M$ associated with Class-A (representing continental air mass) (representing continental air mass) showed ∼1.5 times higher values as compared to those associated with Class-B (representing the Arabian Desert/marine air masses). Moreover, Class-A samples showed ∼95% $Cl^-$ -depletion from sea-salt aerosols, which was also found to be significantly correlated with $OP_M$. These observations not only suggest the importance of free acidity in affecting the chemistry of the marine atmosphere but in the catalytic generation of ROS. Moreover, water-soluble organic nitrogen (WSON) contribute ∼15% to total nitrogen, and the mass fraction of WSON was observed to be positively correlated (R=0.79) with $OP_M$, suggesting water-soluble nitrogenous organics can be highly vulnerable to microorganisms.

Further, $OP_M$ exhibited a significant correlation (R=0.83) with non-sea-salt (nss)-$K^+$, indicating the effect of biomass burning emissions on aerosols OP. Also, the mass fraction of water-soluble (WS)-Mn, WS-Cu, and WS-Zn correlated significantly with $OP_M$, which may be highly susceptible to the health of microorganisms. Our results infer that aerosols aging increase their OP. These results have important implications in assessing the effects of continental aerosols on marine atmospheric boundary layer and ocean biogeochemistry.

*Ship cruise was led by Dr. Arvind Singh, GSDN, PRL*

doi : https://doi.org/10.1021/acsearthspacechem.9b00285

**(A. Patel and N. Rastogi)**

**Characteristics of Water-soluble and Water-Insoluble Brown Carbon Aerosol during a Large-Scale Biomass Burning**

Light absorbing organic aerosol (also known as brown carbon, BrC) can significantly affect Earth's radiation budget and hydrological cycle. Biomass burning (BB) is among the major sources of atmospheric BrC. In this study, day/night pair (10-hour integrated) of ambient $PM_{2.5}$ (particulate matter less than 2.5$\mu$m aerodynamic diameter) were sampled every day before (defined as T1, n=21), during (T2, n=36) and after (T3, n=8) a large-scale paddy-residue burning. The sampling period was during October-November over Patiala (30.2°N, 76.3°E, 250 m AMSL), a site located in the northwestern Indo-Gangetic Plain (IGP). $PM_{2.5}$ concentration varied from ∼90 to 500$\mu$g m$^{-3}$ (average±1 $\sigma$standard deviation: 230 ±114) with the average values of 154±57, 271±122, 156±18 $\mu$g m$^{-3}$ during T1, T2 and T3 periods, respectively, indicating the influence of BB emissions on ambient air quality. The absorption coefficient of BrC at 365 nm ($b_{abs365}$) was calculated from the absorption spectra of water-soluble and methanol-soluble organic carbon measured at 300 to 700 nm. The $b_{abs-365-Methanol}$ was about three times higher than $b_{abs-365-Water}$, suggesting a considerable presence of water-insoluble BrC. Contrasting differences were also observed in the daytime and nighttime values of $b_{abs-365-Water}$ and $b_{abs-365-Methanol}$. Interestingly, $b_{abs-365-Water}$ and $b_{abs-365-Methanol}$ showed a strong correlation with levoglucosan, confirming that BB is an important source for BrC. Further, the levoglucosan showed a strong correlation with potassium ($K^+$) with the slope (0.94), which could be used as a fingerprint for the emissions from paddy-residue burning over the IGP.

*This work was done in collaborative work for providing Logistic support for the sample collection by Dr. Atinderpal Singh and Prof. Darshan Singh (Punjabi University, Patiala).*

doi : http://doi.org/10.1007/s11356-020-09388-7

**(R.V. Satish Kumar and N. Rastogi)**

**Quantification of organic carbon from biomass versus non-biomass burning emissions in fine aerosol**

Biomass burning (BB) is among the major sources of atmospheric pollution with direct short- and long-term climate implications over many regions of the world. It is important to quantify BB contribution to aerosol loading over different geographical regions. However, the role of BB in the mitigation policies is often overlooked due to lack of reliable data on their source strength. In this context, present study quantifies the contribution of BB to ambient organic carbon (OC) in fine aerosol ($PM_1$) over Patiala (30.33°N, 76.40°E; 250m amsl), located in the northwestern Indo-Gangetic Plain.

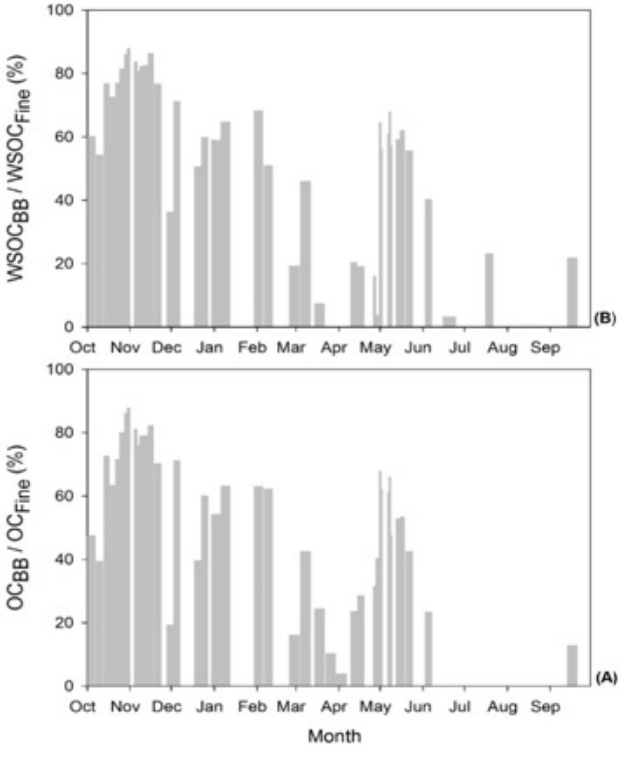


Figure No. 7: Contribution of biomass (BB) to ambient (A) organic carbon (OC) and (B) water-soluble organic carbon (WSOC).

The contribution of BB derived potassium ($K_{BB+}$) to ambient fine $K^+$ is found to be dominant (77±24%) over an annual cycle. Further, regression parameters of OC and $K_{BB+}$ linear relationships are used to quantify the contribution of BB to ambient OC in fine aerosol. The contribution of BB derived OC ($OC_{BB}$) to fine OC varied between 0 and 88% (annual average: 41±30%) (Fig.7A) with higher contribution during autumn (69%), winter (54%) and summer (40%) seasons, and relatively lower contribution during spring (26%) and wet (2%) seasons, suggesting BB is a significant source of ambient fine OC over the study region especially during autumn, winter and summer seasons. Furthermore, the contribution of BB to fine WSOC has also been quantified by employing the same method as used in the case of OC. It ranged from 0 to 88% (annual average: 43±32%) throughout the study period (Fig. 7B). $WSOC_{BB}$ follows the similar temporal trend as exhibited by $OC_{BB}$ with contribution of 75%, 55% and 44% during autumn, winter and summer seasons respectively, whereas it is found to be 14% for spring and 5% for wet season attesting that same sources contribute to $WSOC_{BB}$ and $OC_{BB}$. In nutshell, present study demonstrates that BB is significant source of ambient fine OC and quantifies the contribution of BB to ambient OC, which has important implications in climate models and air quality regulation.

*This work was done in collaboration with logistic support for the sample collection was provided by Prof. Darshan Singh (Punjabi University, Patiala).*

doi : http://doi.org/10.16943/ptinsa/2019/49585

**(A. Singh and N. Rastogi)**

**Effect of tidal cycle on biogeochemistry of a mangrove-dominated tropical estuary**

Based on a 24 hours of time-series study, this study aimed to understand the effects of a tidal cycle on carbon biogeochemistry of a mangrove dominated tropical estuary (the Sundarbans) located in the eastern part of India. Salinity, dissolved oxygen, and pH showed clear tidal variability with relatively higher values during high tide than low tide. Dissolved inorganic carbon (DIC) concentrations varied over a narrow range (1.92 to 2.19 mM) with relatively higher values during low tide; reverse trend, however, was noticed for $\delta^{13}C_{DIC}$ with significant variability (-4.28 to -2.21‰). During low tide, along with estuarine mixing, preliminary evidences for influences of biogeochemical (such as organic carbon mineralization, sulfate reduction, and denitrification) and hydrological processes (porewater exchange) were found on DIC dynamics. The $\delta^{13}C_{DIC}$ – DIC relationship suggested respiration of marine plankton to be one of the possible sources for DIC. Dissolved organic carbon showed tidal influence during high tide with a signal of porewater mediated addition during low tide. Both particulate organic carbon and particulate nitrogen concentrations reached the maximum during low tide with stable isotopic compositions showing predominantly marine signature along with the possibility of biogeochemical modifications within the estuary. Marine water contribution together with organic carbon mineralization and possible porewater influx resulted in ∼214 $\mu$atm higher $_pCO_2$ and 1.13 times higher $FCO_2$ during low tide than high tide. On diurnal basis, the estuary released ∼1348 mg $CO_2$ per $m^2$ of surface area to the regional atmosphere.

doi : https://doi.org/10.1016/j.ecss.2019.106426

**(M. K. Dutta and S. Kumar)**

**Sources and transformations of organic matter in sediments of Asia's largest brackish water lagoon**

This study aimed to understand sources and transformations of organic matter along with cycling of nitrogen and carbon in sediments of two geographically close but ecologically distinct wetlands located on the east coast of India *viz.* Chilika lagoon (Asia's largest brackish water lagoon) and Bhitarkanika mangrove. The study also investigated potential nitrogen loss pathways in the bottom sediments and explored stables isotopes as a proxy for the source identification of sediment organic matter in shallow aquatic ecosystems. For this purpose, the isotopic compositions of organic carbon and nitrogen ($\delta^{13}C_{org}$ and $\delta^{15}N$) and its contents (% Corg and % N) were measured at different depths in sediment cores collected from the Chilika lagoon (eight cores) and Bhitarkanika mangrove forest (three cores). Overall, the mean $\delta^{13}C_{org}$ and % $C_{org}$ in the lagoon were -21.10±0.79‰and 0.84±0.47 %, respectively; whereas the same for mangrove cores were -24.56±0.80‰and 1.04±0.26 %, respectively. Similarly, average $\delta^{15}N$ and %N in the lagoon cores were 4.15±0.63‰and 0.11±0.05 %, respectively; for mangrove cores the values were 4.28±0.50‰and 0.07±0.01 %, respectively. Isotopic composition and elemental ratios indicated organic matter in the sediments of Bhitarkanika mangrove to be a mixture of terrigenous and marine origin with relative dominance of terrestrial influence. A significant increase in $\delta^{13}C_{org}$ of sediment organic matter compared to suspended particulate organic matter in the Chilika indicated

transformation of organic matter in the water or sediment column through mineralization and diagenetic alterations. The $\delta^{15}$N of sediment or particulate organic matter did not show clear evidence of nitrogen loss in the recent past in these two ecosystems through processes such as denitrification. The absence of a relationship between $\delta^{13}C_{org}$ of particulate and sediment organic matter in the Chilika indicated lack of efficient exchange between suspended and sediment organic matter.

doi : https://doi.org/10.1007/s12665-019-8329-6

**(R. Mukherjee and S. Kumar)**

**Gross nitrogen transformation rates in semi-arid tropical soils**

Exacerbated inundations and salt-water intrusions due to sea-level rise can significantly alter the ecology of low-lying coastal drylands by affecting their nutrient cycling and productivity. During this study, controls on production and consumption of nitrogen in soils of semi-arid tropical climate with different levels of vegetation-salinity-moisture condition were investigated using $^{15}$N isotope dilution experiments. For this purpose, soils were collected from five land-types including two in salt flat and one each in grassland, wetland, and an agricultural field. Soils with no vegetation, high salinity, and high moisture (salt flats) showed significant decline in gross production of nitrogen (mineralization rate: 0.21±0.10 mg N kg$^{-1}$ d$^{-1}$; nitrification rate: 0.27±0.17 mg N kg$^{-1}$ d$^{-1}$) compared to soils with vegetation, low salinity, and low moisture (grassland, wetland, and agricultural) (mineralization rate: 2.47±1.74 mg N kg$^{-1}$ d$^{-1}$; nitrification rate: 1.43±1.30 mg N kg$^{-1}$ d$^{-1}$). Backward stepwise regression analysis of the results indicated salinity to be the most important factor controlling nitrogen transformation rates. It is likely that soils undergoing frequent seawater exposure or excessive evaporation may experience slowdown in nitrogen cycling due to salinization leading to reduced nutrient production and consumption. Due to climate change, the areal extent of coastal drylands undergoing such decline in nutrient production is likely to increase eventually leading to loss of productivity and desertification.

doi : https://doi.org/10.1002/ecs2.3034

**(N. Sharma and S. Kumar)**

**Optical chronology and climatic implication of glacial advances from the southern Ladakh Range, NW Himalaya, India**

Puche glacier valley in the NW Ladakh Himalaya is investigated to understand the pattern of glacier advances during the last 30 ka. The study observed preservation of three glacial advances of decreasing magnitude. The oldest moraine representing the Puche Glacier Advance-1 (PGA-1) is optically dated to the early part of the Marine Isotopic Stage (MIS)-2 dated to 31.5±3.3 ka. This advancement persisted until around the global Last Glacial Maxima (LGM) dated to 22.7±1.6 ka. The PGA-2 is optically dated to the post LGM (14.4±1.0 ka) and perhaps was triggered by meltwater pulse cooling (∼1000 years). The youngest PGA-3 remains undated and could be of Holocene age. This tend to suggest that contribution of moisture through westerlies was the major driver of glacier advances during the MIS-2. Importantly, the study is at variance with the previous suggestions that recommended monsoon driven glacier advances in the NW Himalaya. Further, the OSL ages when compared with the previously published exposure ages ($^{10}$Be) are significantly younger by a magnitude. The study therefore, call for employing multiple dating methods to minimize the uncertainty both in terms of age estimate of the events and the associated climatic interpretation.

doi : https://doi.org/10.1016/j.palaeo.2019.109505

**(A.D.Shukla)**

**Investigating the sensitivity of glaciers to climate variability since the MIS-2 in the upper Ganga catchment (Saraswati valley), Central Himalaya**

Moraines, outwash gravel terraces, fluvial drapes and lacustrine sequences are used to infer the pattern of glacial fluctuations in the Saraswati valley (upper Ganga catchment). Located in transitional climatic zone between dry steppe of the Tibetan plateau in the north and sub-humid higher Himalaya in the south, the Saraswati valley has preserved evidence of four glacier advances. These are identified as the Saraswati Glacial Stage (SGS)-1 (oldest) to SGS-4 (youngest). Based on the relative dating and optical ages the SGS-1 is ascribed to pre-Marine Isotopic Stage (MIS)-2. The SGS-2 is dated to the 24.5±2.8 – 21.2±2.0ka (MIS-2); the SGS-3 is speculatively ascribed to the Younger Dryas (YD) and the SGS-4 is suggested to be of the mid-Holocene (∼6ka) age. The deglaciation is represented by outwash gravel terraces, impounded sedimentary (lacustrine) sequences and fluvial drapes overlying and abutting the moraines are dated to early-mid (11.9±0.9 – 7.5±0.6ka) and late Holocene (3.3±0.2 – 1.7±0.3ka) intensified/moderate Indian Summer Monsoon. Considering the timing of glacial advances and stand-still condition, it is proposed that across the orographic barrier (rain shadow valleys), glaciers responded sensitively to the intensified anticyclonic flow of the cooler Mid-latitude Westerlies; implying that in a monsoon dominated transient climatic zone, even the rain shadow valleys responded sensitively to temperature changes.

doi : https://doi.org/10.1016/j.geomorph.2019.106854

**(A.D. Shukla)**

**Evolution of the Proterozoic Vindhyan Basin, Rajasthan, India: insights from geochemical provenance of siliciclastic sediments**

The Vindhyan Basin of western India is a part of the largest Proterozoic sedimentary basin of the Indian subcontinent. Deposited in a largely shallow marine environment, the sedimentary sequence of the basin, known as the Vindhyan Supergroup, is believed to hold clues to our understanding of the evolution of life and climate during the Proterozoic. However, study pertaining to the evolutionary history still remain in embryonic stage. The present study tried to propose a model for the evolutionary history of the Vindhyan Basin based

geochemical and isotopic compositions of siliciclastic sediments (province identification). Our study indicate that the basin opened up in a foreland setting during an event that was contemporaneous with the amalgamation of the supercontinent Columbia. In the Lower Vindhyans, most of the sediments were derived from the basement gneisses (BGC-I & II) and a younger differentiated magmatic arc, whereas the >1.7 Ga rocks of the Aravalli and Delhi supergroups formed the source area for the Upper Vindhyans. In comparison to their counterparts in the eastern sector in the Son Valley, the Semri and Kaimur groups of the western sector had a relatively younger provenance; whereas, the Rewa and Bhander groups of both the sectors appear to have shared geochemically similar provenances. Unlike its counterpart in the eastern sector, the provenance of the sediments in the western sector had remained constant across the supposedly 400 million years break in sedimentation between the Lower and the Upper Vindhyans. However, a change in the provenance is observed during the transition from the Kaimur to Rewa group in the western sector which we infer to be a break in the deposition.

doi : https://doi.org/10.1080/00206814.2019.1594412

**(A.D. Shukla, B.V. George and J.S. Ray)**

**Geochemical signatures of Late Paleocene sandstones from the Sanu Formation, Jaisalmer basin, western India: Implication for provenance, weathering and tectonic setting**

Sandstones of the Sanu Formation from Jaisalmer basin, western India were studied for major, trace and rare earth element (REE) geochemistry to deduce their paleo-weathering, tectonic setting, source rock characteristics and provenance. Geochemical analysis suggest that these sandstones can be grouped into sub-arkose type of sandstones, which is further supported by petrographic observations of the prepared thin sections of these rocks. The chemical index of alteration (CIA) which defines the nature of these rocks in the basin suggest that these rocks have suffered intense chemical weathering. Further the major, trace and rare earth elements concentration pattern reveals that the sediments of the Sanu Formation were derived from silicic rock sources. The trace elemental discrimination diagrams specifically (Gd/Yb) N against $Eu/Eu^{*}$ suggest the Archean provenance as source possibly Aravallis for the studied samples.

doi : https://doi.org/10.1007/s12040-020-1358-4

**(A. Patra and A.D. Shukla)**

**New evidence of early Iron Age to Medieval settlements from the southern fringe of Thar Desert (western Great Rann of Kachchh), India: Implications to climate-culture co-evolution**

Two hitherto unexplored settlements at Karim Shahi and Vigakot are reported from the uninhabited hyper-arid region of the western Great Rann of Kachchh (GRK), located near southern fringe of Thar Desert, Gujarat, NW India. The archaeological evidence, supported by radiocarbon and optical chronology indicate presence of settlement from the Early Iron Age to Early Historic (∼3100 - 2300 years B.P.) and Historic to Medieval (∼1500 - 900 years B.P.) periods. This would imply that following the Harappan decline, the GRK was still a hospitable terrain for the sustenance of human settlement's during the Early Iron Age. Isotopic and micro-botanical evidence indicate that relatively higher rainfall than today sustained the hydrological system until around the Medieval period. We propose that the early withdrawal of the late Holocene Inter Tropical Convergence Zone (ITCZ) and resultant monsoon decline accounts for the abandonment of settlement in the western (Sindh - Baluchistan) domain. As a consequence, the rivers in the western domain dried early, while the fluvial system in the southern/eastern domain (Sorath/Cholistan in Gujarat/Ghaggar-Hakra-Nara interfluve) was sustained due to monsoonal rain at least up to 1600 years B.P. The settlements were subsequently disrupted due to a combination of hyper-arid climate and infrequent tectonic activity sometime between the late Medieval and recent time.

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**(A.D. Shukla and M.G. Yadava)**

**Surplus Supply of Bioavailable Nitrogen through $N_2$ fixation to Primary Producers during Autumn in the Eastern Arabian Sea**

Diazotrophic $N_2$ fixation has received recent appreciation as a major source of bioavailable nitrogen in the global oceans. Diazotrophs flourish in warm, stratified, calm and nutrient replete conditions in the ocean. Such conditions prevail during spring and autumn seasons in the Arabian Sea. Some previous experimental studies conducted during spring have suggested the highest rates of $N_2$ fixation in the eastern Arabian Sea when compared to the other oceans, but there are no such records during the autumn season. In addition, modelling studies have also suggested high rates of annual $N_2$ fixation in the Arabian Sea. In this study, we conducted isotopic enriched tracer incubation experiments during autumn 2010 in the eastern Arabian Sea to estimate $N_2$ fixation rates and primary production. Unlike the previous studies conducted in this region, we did not witness any diazotrophic bloom, but our $N_2$ fixation rates (1,300 - 2,500 $\mu$mol N $m^{-2}$ $d^{-1}$) were still comparable to the rates reported in previous studies and among the highest rates observed in the global oceans. Although it is unclear what species of diazotrophs fix such large amount of $N_2$, our data suggest an important role of excess phosphate to sustain $N_2$ fixation during autumn. Most intriguing finding of our study is that the $N_2$ fixation supplies surplus amount of bioavailable nitrogen required for primary producers during autumn.

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**(A. Singh, N. Gandhi & R. Ramesh)**

# Theoretical Physics

**Charm quark diffusion in quark gluon plasma**

We calculate the transport coefficients i.e. the drag and momentum diffusion, of a heavy quark like charm or bottom in a thermalised plasma of light quarks in the background of Polyakov loop. The quark thermal mass and the gluon Debye mass are calculated in anon-trivial Polyakov loop background. The constituent quark masses and the Polyakov loop is estimated within a Polyakov loop quark meson (PQM) model. The relevant scattering amplitudes for heavy quarks and light partons in the background of nontrivial Polyakov loop have been estimated within the matrix model. We have also compared the results with the Polyakov loop parameters estimated from lattice simulations. We studied temperature and momentum dependence of the charm quark drag and diffusion coefficients. It is observed that the temperature dependence of the drag coefficient is quite weak, which, may play a key role in understanding heavy quark observables at RHIC and LHC energies.

doi : https://doi.org/10.1103/PhysRevD.101.054027

**(Hiranmaya Mishra, Balbeer Singh, Aman Abhishek (work done in collaboration with Santosh Das from IIT Goa.))**

**Dilepton production from quark gluon plasma with vorticity**

We study the effect of vorticity present in heavy ion collisions (HICs) on the temperature evolution of hot quark-gluon plasma in the presence of spin-vorticity coupling. The initial global rotation entails a nontrivial dependence of the longitudinal flow velocity on the transverse coordinates and also develops a transverse velocity component that depends upon longitudinal coordinate. Both of these velocities leads to a 2+1 dimensional expansion of the fireball. It is observed that with the finite vorticity and spin-polarization fireball cools faster in comparison with the case without vorticity leading to a early hadronisation. Furthermore, it is also observed that as the consequence of this there is a suppression of thermal dilepton production from QGP.

doi : https://doi.org/10.1103/PhysRevD.100.014016

**(Jitesh Bhatt, Balbeer Singh and Hiranmaya Mishra)**

**Heavy quark transport in a viscous semi QGP**

We study the effect of shear and bulk viscosities on the heavy quark transport coefficient within the matrix model of semi QGP. Dissipative effects are incorporated through the first-order viscous correction in the quark/antiquark and gluon distribution function. It is observed that while the shear viscosity effects reduces the drag of heavy quark the bulk viscosity effects increase the drag and the diffusion coefficients of heavy quark. For finite values of $\eta/s$ and $\xi/s$, Polyakov loop further decreases the drag and the diffusion coefficients as compared to perturbative QCD.

doi : https://doi.org/10.1103/PhysRevD.101.054027

**(Balbeer Singh and Hiranmaya Mishra)**

**Transport coefficients of hot and dense hadron gas in a magnetic field: a relaxation time approach**

We estimate various transport coefficients of hot and dense hadronic matter in the presence of magnetic field. The estimation is done through solutions of the relativistic Boltzmann transport equation in the relaxation time approximation.We have investigated the temperature and the baryon chemical potential dependence of these transport coefficients. Explicit calculations are done for the hadronic matter in the ambit of hadron resonance gas model. We estimate thermal conductivity, electrical conductivity and the shear viscosity of hadronic matter in the presence of a uniform magnetic field. Magnetic field, in general, makes the transport coefficients anisotropic. It is also observed that all the transport coefficients perpendicular to the magnetic field are smaller compared to their isotropic counterpart.

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**(Arpan Das, Hiranmaya Mishra (work done in collaboration with Dr. Ranjita K Mohapatra from IIT Bombay, Mumbai.))**

**Chiral susceptibility in Nambu Jona Lasinio model: a Wigner function approach**

We estimate here chiral susceptibility at finite temperature within the framework of the Nambu-Jona-Lasinio model (NJL) using the Wigner function approach. We also estimate it in the presence of chiral chemical potential as well as a non vanishing magnetic field (B). We

use medium separation regularization scheme (MSS) to calculate the chiral condensate and corresponding susceptibility. It is observed that for a fixed value of chiral chemical potential, transition temperature increases with the magnetic field. While for the fixed value of the magnetic field, transition temperature decreases with chiral chemical potential. For a strong magnetic field, we observe non degeneracy in susceptibility for up and down type quarks.

doi : https://doi.org/10.1103/PhysRevD.100.094030

**(Arpan Das, Deepak Kumar, Hiranmaya Mishra)**

**Electrical conductivity and Hall conductivity of hot and dense quark gluon plasma in a magnetic field: a quasi particle approach**

We estimate here the electrical and Hall conductivity using a quasiparticle approach for quark matter. We use a Boltzmann kinetic approach in presence of external magnetic field. We confront the results of model calculations with Lattice QCD simulations for vanishing magnetic field. In general electrical conductivity decreases with magnetic field. The Hall conductivity on the other hand can show a non monotonic behaviour with magnetic field due to an intricate interplay of behaviour of relaxation time and strength of the magnetic field. We argue for vanishing quark chemical potential Hall conductivity vanishes and quark gluon plasma with finite quark chemical potential can show Hall effect. Both electrical conductivity and Hall conductivity increases with increasing quark chemical potential.

doi : https://doi.org/10.1103/PhysRevD.99.094031

**(Arpan Das, Hiranmaya Mishra (work done in collaboration with Dr. Ranjita K Mohapatra from IIT Bombay, Mumbai.))**

**Hadron resonance gas with repulsive mean field interaction: Thermodynamics and transport properties**

We discuss the interacting hadron resonance gas model to describe the thermodynamics of hadronic matter. While the attractive interaction between hadrons is taken care of by including all the resonances with zero width, the repulsive interactions are included by considering density-dependent mean field potentials. The bulk thermodynamic quantities are confronted with the lattice quantum chromodynamics simulation results at zero as well as at finite baryon chemical potential. We further estimate the shear and bulk viscosity coefficients of hot and dense hadronic matter within the ambit of this interacting hadron resonance gas model.

doi : https://doi.org/10.1103/PhysRevD.100.074015

**(Hiranmaya Mishra (work done in collaboration with G. Kadam of Sivaji University Kolhapur))**

**Viscosity calculations from Hadron Resonance Gas model: Finite size effect**

We review here the microscopic calculation of transport coefficients like shear and bulk viscosities in the framework of hadron resonance gas model, where a special attention is explored on the effect of finite system size. The standard expressions of transport coefficients, obtained from relaxation time approximation of kinetic theory or diagrammatic Kubo-type formalism, carry mainly two temperature dependent components – thermodynamical phase space and relaxation time of medium constituent. Owing to quantum effect of finite system size, thermodynamical phase space can be reduced as its momentum distribution will be started from some finite lower momentum cut-off instead of zero momentum. On the other hand, relaxation time of hadrons can also face finite size effect by considering only those relaxation scales, which are lower than the system size. Owing to these phenomenological issues, we have proposed a system size dependent upper bound of transport coefficients for ideal HRG model, whose qualitative technique may also be applicable in other models. This finite size prescription may guide to shorten the broad numerical band, within which earlier estimated values of transport coefficients for hadronic matter are located. It is also suspected that the hadronic matter may not be far from the (nearly) perfect fluid nature like the quark gluon plasma.

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**(Hiranmaya Mishra (work done in collabation with S. Ghosh of IIT Gandhinagar, Sabyasachi Ghosh of IIT Bhilai, S. Samanta of NISER Bhubaneswar))**

**Impact of magnetic field on shear viscosity of quark matter in NambuJona-Lasinio model**

We have investigated the shear viscosity of quark matter in the presence of a strong uniform magnetic field background in which the Nambu-Jona-Lasinio model has been considered to describe the magnetothermodynamical properties of the medium. In the presence of magnetic field, the shear viscosity coefficient gets split into different components because of anisotropy in tangential stress of the fluid. Four different components can be merged to two components in the strong field limit, at which the collisional width of the quark becomes much lower than its synchrotron frequency. A simplified contact diagram of quark-quark interaction can estimate a small collisional width, for which the strong field limit expressions are exactly applicable, although for the Relativistic Heavy Ion Collider or LHC matter, one can expect a large thermal width, for which generalized four-component viscosities are necessary. We have explored all these different possible cases in the thermodynamical framework of the Nambu–Jona-Lasinio model.

doi : https://doi.org/10.1103/PhysRevD.100.034024

**(Hiranmaya Mishra (work done in collabation with Sabyasachi Ghosh of IIT Bhilai, P. Mohanty of NISER Bhubaneswar, B. Chatterjee of IIT Indore and A. Mukharjee of SINP, Kolkata))**

**Constraining a general U(1)$'$ inverse seesaw model from vacuum stability, dark matter and collider**

We consider a class of gauged U(1) extensions of the Standard Model (SM), where the light neutrino masses are generated by an inverse seesaw mechanism. In addition to the three right handed neutrinos, we add three singlet fermions and demand an extra $Z_2$ symmetry

under which, the third generations of both of the neutral fermions are odd, which in turn gives us a stable dark matter candidate. We express the U(1) charges of all the fermions in terms of the U(1) charges of the standard model Higgs and the new complex scalar. We study the bounds on the parameters of the model from vacuum stability, perturbative unitarity, dark matter relic density, and direct detection constraints. We also obtain the collider constraints on the $Z'$ mass and the $U(1)'$ gauge coupling and compare the constraints coming from different sectors.

doi : https://doi.org/10.1103/PhysRevD.101.055026

**(S. Goswami, Vishnudath. K.N (work was done in collaboration Arindam Das from Osaka University and Takaki Nomura from Kias, Seoul.))**

**Enhancing the hierarchy and octant sensitivity of ESS$\nu$SB in conjunction with T2K, NOvA and ICAL@INO**

The main aim of the ESS$\nu$SB proposal with the detector at Sweden is the discovery of the leptonic CP phase $\delta_{\rm CP}$ with a high significance ($5\sigma$ for 50% values of $\delta_{\rm CP}$) by utilizing the physics at the second oscillation maxima of the $iP_{\mu e}$ channel. We explored the capability of this experiment to determine hierarchy and octant. We showed that combining the ESS$\nu$SB experiment with the atmospheric neutrino data from the proposed India-based Neutrino Observatory(INO) experiment can result in an increased sensitivity to mass hierarchy. In addition, we also combine the results from the ongoing experiments T2K and NO$\nu$A assuming their full runtime and present the combined sensitivity of ESSnuSB + INO + T2K + NO$\nu$A.We show that while by itself ESS$\nu$SB can have up to $3\sigma$ hierarchy sensitivity, the combination of all the experiments can give up to $5\sigma$ sensitivity depending on the true hierarchy-octant combination.The octant sensitivity of ESS$\nu$SB is low by itself. However the combined sensitivity of all the above experiments can give up to $3\sigma$ sensitivity depending on the choice of true hierarchy, octant and the CP phase, .We discuss the various degeneracies and the synergies that lead to the enhanced sensitivity when combining different experimental data.

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**(K. Chakrbarti, S. Goswami, C. Gupta (work was done in collaboration with Tarak Thakore from Valencia University))**

**A New Sensitivity Goal for Neutrino-less Double Beta Decay Experiments**

We study the implications of the Dark-LMA solution to the solar neutrino problem for neutrino-less double beta decay ( $0\nu\beta\beta$). We show that while the predictions for the effective mass governing $0\nu\beta\beta$ remains unchanged for the inverted mass scheme, that for normal ordering becomes higher for the Dark-LMA parameter space and moves into the "desert region" between the two. This sets a new goal for sensitivity reach for the next generation experiments if no signal is found for the inverted ordering by the future search programmes.

doi : https://doi.org/10.1103/PhysRevD.99.095038

**(Vishnudath. K.N, Srubabati Goswami (work was done in collaboration with Sandhya Choubey from HRI, Allahabad.))**

**Electroweak Vacuum metastability in a natural minimal Type-III Seesaw Model**

We study the minimal type-III seesaw model in which we extend the SM by adding two SU (2) L triplet fermions with zero hypercharge to explain the origin of the non-zero neutrino masses and mixing. We show that the naturalness conditions and the limits from lepton flavor violating decays provide very stringent bounds on the model along with the constraints on the stability/metastability of the electroweak vacuum. We perform a detailed analysis of the model parameter space including all the constraints for both normal as well as inverted hierarchies of the light neutrino masses. We find that most of the region that are allowed by lepton flavor violating decay and naturalness fall in the metastable region.

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**(S. Goswami, Vishnudath. K.N. (work was done in collaboration with Najimuddin Khan from IISC, Bangalore.))**

**$B \to K_2^*(1430)\ell^+\ell^-$ distributions in Standard Model and beyond at large recoil**

The rare decay $B \to K_2^*(1430)\ell^+\ell^-$ is studied within and beyond the standard model by exploiting the symmetries of the form-factors that emerge when the final state meson carries a large fraction of the available energy. In this limit, optimised observables are found to be less sensitive to hadronic contributions and are therefore clean. The mode is found to have a large branching fraction within the standard model and is thus expected to be a good study candidate at the current and future experiments. Detailed predictions are provided for the optimised observables within the standard model as well as in the scenarios that seem to be favoured by other $b \to s\ell^+\ell^-$ data.

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**(D. Das, Bharti Kindra, G. Kumar, Namit Mahajan)**

**Probing new physics in semileptonic $\Lambda_b$ decays**

Taking a cue from the recent hints of deviations from the standard model expectations, both in the charged current as well as neutral current B-decays, a model independent analysis of $b \to c\ell\nu_\ell$ is performed and the parameter space is tightly constrained employing the available experimental information on decays mediated by this quark level process. The constrained parameters are used to study the processses $\Lambda_b \to (\lambda_c, p)\ell\nu_\ell$, including forward-backward asymmetry and polarization asymmetries as well as impact on lepton flavour universality.

doi : https://doi.org/10.1140/epjc/s10052-019-7183-8

**(A. Ray, Suchismita Sahoo, R. Mohanta)**

**Collider signature of $\mathrm{V}_2$ Leptoquark with $b \to s$ flavour observables**

The role of $\mathrm{V}_2$ leptoquark is carefully studied with repect to flavour observables and the recent tensions in the data, both in the $b \to c$ charged current as well as in $b \to s$ neutral current processes, in particular the component having electric charge 4/3. It is found that a considerable portion of the parameter space consistent with flavour data gets excluded once the collider constraints are taken into account.

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**(A. Biswas, Avirup Shaw, A.K. Swain)**

**Reconciling dark matter, $\mathrm{R}_{\mathrm{K}^{(*)}}$ anomalies and $(g-2)_\mu$ in an $\mathrm{L}_\mu - \mathrm{L}_\tau$ scenario**

A unifed and anomaly free scenario with an additional $\mathrm{U}(1)_{\mathrm{L}_\mu - \mathrm{L}_\tau}$ gauge symmetry is proposed that simulataneously solves $\mathrm{R}_{\mathrm{K}^{(*)}}$ and muon $(g-2)_\mu$ discrepancies and at the same time provides a viable dark matter candidate. The model requires the intoduction of an additional scalar doublet, a real singlet and and a coloured fermion having vectorial interactions under the additional $\mathrm{U}(1)$. Low mass dark matter (¡ 60 GeV) regime is still allowed within this scenario and the model is compatible with $\mathrm{B} \to \mathrm{X}_s\gamma$ data and is capable of explaining neutrino masses and mixings if three right handed neutrinos are added.

doi : https://doi.org/10.1007/JHEP05(2019)165

**(A. Biswas, Avirup Shaw)**

**Looking for $\mathrm{B} \to \mathrm{X}_s l^+ l^-$ in non-minimal Universal Extra Dimensional model**

Non-vanishing boundary localised terms significantly modify the mass spectrum and various interactions among the Kaluza-Klein excited states of 5-Dimensional Universal Extra Dimensional scenario. In this scenario the contributions of Kaluza-Klein excitations of gauge bosons and third generation quarks for the decay process $\mathrm{B} \to \mathrm{X}_s l^+ l^-$ incorporating next-to-leading order QCD corrections are computed and branching ratio as well as Forward Backward asymmetry are obtained. Also considering the constraints from other $b \to s$ observables and electroweak precision data, lower limit on the inverse of the radius of compactification $\mathrm{R}^{-1}$ as high as$\geq 760$GeV are obtained.

doi : https://doi.org/10.1103/PhysRevD.99.115030

**(Avirup Shaw)**

**Model independent analysis of $\mathrm{B}^* \to \mathrm{P}\ell\nu_\ell$**

Taking a cue from the recent flavour anomalies in the charged current interactions, a model independent analysis of excited B-meson semileptonic decays into pseudoscalars is carried out to check for hints of physics beyond the standard model. Branching ratios for different modes, with vector and scalar operators, are obtained after accounting for contraints from other charged current modes and it is found that for vector type operators, the deviation from the standard model is large.

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**(Atasi Ray, Suchismita Sahoo, Rukmani Mohanta)**

**Generalised $\mu - \tau$ symmetries and calculable gauge kinetic and mass mixing in $\mathrm{U}(1)_{\mathrm{L}_\mu - \mathrm{L}_\tau}$ models**

Extension of the standard model with an abelian $\mathrm{L}_\mu - \mathrm{L}_\tau$ gauge symmetry is studied. Global symmetries which lead to predictable gauge kinetic and mass mixing have been outlined and their interplay with lepton mixing is discussed. It is shown that the spontaneous breaking of these symmetries can lead to phenomenologically consistent lepton mixing and also generates finite and calculable values of kinetic and mass mixing parameters at one or two loop order depending on the underlying symmetry.

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**(Anjan S. Joshipura, Namit Mahajan, Ketan M. Patel)**

**Proton decay in flux compactifications**

Computation of the proton lifetime is carried out in a grand unified theory based on six dimensional spacetime. The extra two spatial dimensions are compactified with a magnetic flux in compact dimensions. Quantisation of flux gives rise to three generations of quarks and leptons and successfully account for their observed masses and mixings. Our analysis of proton decay leads to the conclusion that the proton lifetime must be close to the current experimental lower bound. Moreover, we find that the branching ratios for the decay channels $p \to e^+\pi^0$ and $p \to \mu^+\pi^0$ are of similar size, in fact the latter one can even be dominant. This is due to flavour non-diagonal couplings of heavy vector bosons together with large off-diagonal Higgs couplings, which appears to be a generic feature of flux compactifications.

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**(Ketan M. Patel (in collaboration with W. Buchmuller (DESY, Germany)))**

**Bivariate $q$-normal distribution for transition strengths distribution from $k$-body random matrix ensembles**

Recently, we have established, via lower order moments, that the univariate q-normal distribution, which is the weight function for $q$-Hermite polynomials, describes the ensemble averaged eigenvalue density from many-particle random matrix ensembles generated by $k$-body interactions. These ensembles are generically called

embedded ensembles of $k$-body interactions [EE($k$)] and their GOE and GUE versions are called EGOE($k$) and EGUE($k$) respectively. Going further, the lower order bivariate reduced moments of the transition strength densities, generated by EGOE($k$) [or EGUE($k$)] for the Hamiltonian and an independent EGOE($t$) for the transition operator O that is $t$-body, are used to establish that the ensemble averaged bivariate transition densities indeed follow the bivariate $q$-normal distribution. Derived are also formulas for the bivariate correlation coefficient $\rho$ and the $q$ values as a function of the particle number $m$, number of single particle states N that the particles are occupying and the body ranks $k$ and $t$ of H and O respectively. In addition, using the bivariate $q$ normal form a formula for the chaos measure number of principal components (NPC) in the transition strengths from a state with energy E is derived.

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**(V.K.B. Kota (work is carried out with Manan Vyas (UNAM, Cuernavaca, Mexico)))**

**Deformed shell model results for coherent and incoherent WIMP- and neutrino- nucleus scattering**

Dark matter detection is perhaps the most important research topic in physics and the neutrino-nucleus scattering is closely related to dark matter detection as this forms the back ground in these experiments. The event rates for WIMP-nucleus and neutrino-nucleus scattering processes, expected to be detected at ton-scale rare-event detectors, are investigated. The nuclear structure calculations, for the needed spin structure functions and form factors for protons and neutrons, performed in the context of the Deformed Shell Model, are based on Hartree-Fock intrinsic states with angular momentum projection and band mixing for both the coherent and incoherent channels. The chosen nuclear isotopes are $^{23}$Na, $^{40}$Ar, $^{73}$Ge, $^{127}$I, $^{133}$Cs and $^{133}$Xe and they correspond to the target nuclei of current and future experiments looking for WIMP and neutrino-nucleus events. Our predictions in the high recoil energy tail, show that detectable distortions of the measured (expected) signal may be interpreted through the inclusion of the non-negligible incoherent channels.

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**(V.K.B. Kota (work is carried out with R. Sahu (NIST, Berhampur) and T.S. Kosmas and D.K. Papoulias (University of Ioannina, Greece)))**

**Quadrupole properties of the eight $\mathrm{SU}(3)$ algebras in $(sdgi)$ space**

With nucleons occupying an oscillator shell $\eta$ there are $2^{[\frac{\eta}{2}]}$ number of SU$(3)$ algebras; $[\frac{\eta}{2}]$ is the integer part of $\eta/2$. Analyzing the first non trivial situation with four SU$(3)$ algebras in $(sdg)$ space, demonstrated recently is that they generate quite different quadrupole properties though they all generate the same spectrum. More complex situation is with eight SU$(3)$ algebras in $(sdgi)$ space and this year the quadrupole properties generated by these eight algebras are analyzed first using the more analytically tractable interacting boson model. In addition, shell model codes and the closely related deformed shell model are used with two examples of nucleons in $sdgi$ space. It is shown that in general six of the $\mathrm{SU}(3)$ algebras generate prolate shape and two oblate shape. Out of the six prolate generating algebras, two of them generate quite small quadrupole moments for the low-lying states.

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**(V.K.B. Kota (work is carried out with R. Sahu (NIST, Berhampur) and P.C. Srivastava (IIT-Roorkee)))**

**Relaxation of Shannon entropy for trapped interacting bosons with dipolar interactions**

We have studied the quantum many-body dynamics and entropy production triggered by an interaction quench of few dipolar bosons in an external harmonic trap. By solving the time-dependent many-body Schrödinger equation using an in-principle numerically exact many-body method called the multiconfigurational time-dependent Hartree method for bosons (MCTDHB) - studied are dynamical measures involving the time evolution of the occupation in the natural orbitals and normalized first- and second-order Glauber's correlation functions. In particular, examined is the relaxation dynamics of the Shannon entropy. We have observed significant effects of the non-local part of the repulsive dipolar interaction. The relaxation process is very fast for dipolar bosons with a clear signature of a truly saturated maximum entropy state. The entropy production and the occurrence of correlations and loss of coherence in the system are connected. We identify the long-time relaxed state as a many-body state retaining only diagonal correlations in the first-order correlation function and building up anti-bunching effect in the second-order correlation function.

**(V.K.B. Kota (work is carried out with Barnali Chakrabarti (Presidency University, Kolkata)))**

**$\mathrm{SU}(3)$ symmetry in atomic nuclei**

A book on 'SU(3) Symmetry in Atomic Nuclei' is written (to be published by Springer Nature) with 12 Chapters and they are: (i) Introduction; (ii) $\mathrm{SU}(3)$ algebra in nuclei: preliminaries; (iii)$\mathrm{SU}(3)$ Wigner-Racah algebra I; (iv) $\mathrm{SU}(3)$ Wigner-Racah algebra II; (v) $\mathrm{SU}(3) \supset \mathrm{SO}(3)$ Integrity Basis Operators; (vi) $\mathrm{SU}(3)$ in shell model based approaches and their applications; (vii) $\mathrm{SU}(3)$ in interacting boson models; (viii) $\mathrm{SU}(3)$ in interacting boson-fermion models; (ix) Extended applications of $\mathrm{SU}(3)$; (x)Statistical nuclear physics with $\mathrm{SU}(3)$; (xi) Multiple $\mathrm{SU}(3)$ algebras in interacting boson model and shell model; (xii) Summary and future outlook. In addition, the book contains five Appendices: (i) Angular Momentum Algebra; (ii) Elements of $\mathrm{U}(n)$ Lie algebra and its subalgebras; (iii) Asymptotic Nilsson wavefunctions; (iv) Correspondence between $\mathrm{SU}^{\mathrm{BF}^2}(3)$ irreps and 2 quasi-particle Nilsson configurations for $\eta = 3$ shell; (v) Bivariate moments, cumulants and Edgeworth expansion.

**(V.K.B. Kota)**

**Enhancement of the Bose glass phase in the presence of an artificial gauge field**

We examine the effects of an artificial gauge field and finite temperature in a two-dimensional disordered Bose-Hubbard model. The disorder considered is diagonal and quenched in nature. A signature of disorder in the Bose-Hubbard model is the Bose glass phase. Our work shows that the introduction of an artificial gauge field enhances the domain of the Bose glass phase in the phase diagram. Most importantly, the size of the domain can be tuned with the strength of the artificial gauge field. The introduction of finite-temperature effects is essential to relate theoretical results with the experimental realizations. For our studies we use the single-site and cluster Gutzwiller mean-field theories. The results from the latter are more reliable as it better describes the correlation effects. Our results show that the Bose glass phase has a larger domain with the latter method.

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**(Sukla Pal, Rukmani Bai, Soumik Bandyopadhyay, K. Suthar, and D. Angom)**

**Splitting of singly and doubly quantized composite vortices in two-component Bose-Einstein condensates**

We study numerically the dynamical instabilities and splitting of singly and doubly quantized composite vortices in two-component Bose-Einstein condensates harmonically confined to quasi two dimensions. In this system, the vortices become pointlike composite defects that can be classified in terms of an integer pair $(\kappa_1, \kappa_2)$ of phase winding numbers. Our simulations based on zero-temperature mean-field theory reveal several vortex splitting behaviors that stem from the multicomponent nature of the system and do not have direct counterparts in single-component condensates. By calculating the Bogoliubov excitations of stationary axisymmetric composite vortices, we find nonreal excitation frequencies (i.e., dynamical instabilities) for the singly quantized $(1,1)$ and $(1,-1)$vortices and for all variants of doubly quantized vortices, which we define by the condition $\max_{j=1,2}|\kappa_j| = 2$. While the short-time predictions of the linear Bogoliubov analysis are confirmed by direct time integration of the Gross-Pitaevskii equations of motion, the time integration also reveals intricate long-time decay behavior not captured by the linearized dynamics. First, the $(1,\pm1)$ vortex is found to be unstable against splitting into a $(1,0)$ vortex and a $(0,\pm1)$ vortex. Second, the $(2,1)$ vortex exhibits a two-step decay process in which its initial splitting into a $(2,0)$ vortex and a $(0,1)$ vortex is followed by the off-axis splitting of the $(2,0)$ vortex into two $(1,0)$ vortices. Third, the $(2,-2)$ vortex is observed to split into a $(-1,1)$ vortex, three $(1,0)$ vortices, and three $(0,-1)$ vortices. Each of these splitting processes is the dominant decay mechanism of the respective stationary composite vortex for a wide range of intercomponent interaction strengths and relative populations of the two condensate components and should be amenable to experimental detection. Our results contribute to a better understanding of vortex physics, hydrodynamic instabilities, and two-dimensional quantum turbulence in multicomponent superfluids.

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**(Soumik Bandyopadhyay, Arko Roy, and D. Angom (work done in collaboration with Dr. Pekko Kuopanportti from the University of Helsinki, Finland))**

**Quantum phases of canted dipolar bosons in a two-dimensional square optical lattice**

We consider a minimal model to describe the quantum phases of ultracold dipolar bosons in two-dimensional (2D) square optical lattices. The model is a variation of the extended Bose-Hubbard model and apt to study the quantum phases arising from the variation in the tilt angle $\theta$ of the dipolar bosons. At low tilt angles $0^\circ \lesssim \theta \lesssim 25^\circ$, the ground state of the system are phases with checkerboard order, which could be either checkerboard supersolid or checkerboard density wave. For high tilt angles $35^\circ \lesssim \theta \lesssim 55^\circ$, phases with striped order of supersolid or density wave are preferred. In the intermediate domain $25^\circ \lesssim \theta \lesssim 35^\circ$ an emulsion or SF phase intervenes the transition between the checkerboard and striped phases. The attractive interaction dominates for $\theta \lesssim 55^\circ$, which renders the system unstable and there is a density collapse. For our studies we use Gutzwiller mean-field theory to obtain the quantum phases and the phase boundaries. In addition, we calculate the phase boundaries between an incompressible and a compressible phase of the system by considering second order perturbation analysis of the mean-field theory. The analytical results, where applicable, are in excellent agreement with the numerical results. In our study, the incompressible phases have average occupancy per site $\rho \leq 1$, but, the compressible phases can have $\rho > 1$.

doi : https://doi.org/10.1103/PhysRevA.100.053623

**(Soumik Bandyopadhyay, Rukmani Bai, Sukla Pal, K. Suthar, and D. Angom (work done in collaboration with Dr. Rejish Nath from IISER Pune.))**

**Electric dipole polarizability of group-13 ions using perturbed relativistic coupled-cluster theory: Importance of nonlinear terms**

We compute the ground-state electric dipole polarizability $\alpha$ of the group-13 ions using the perturbed relativistic coupled-cluster theory. To account for the relativistic effects and quantum electrodynamical corrections, we use the Dirac-Coulomb-Breit Hamiltonian with the corrections from the Uehling potential and the self-energy. The effects of triple excitations are considered perturbatively in the theory. Our results for polarizability are in good agreement with previous theoretical results for all the ions. From our results we find that the nonlinear terms in perturbed relativistic coupled-cluster theory have significant contributions and must be included to obtain accurate value of dipole polarizability for group-13 ions. For the correction from the Breit interaction, we find that it is largest for $Al^+$ and decreases with increasing Z. The corrections from the vacuum polarization and the self-energy increases with increasing Z.

doi : https://doi.org/10.1103/PhysRevA.101.012503

**(D. Angom (work done in collaboration with Dr. B. K. Mani and R. Kumar from IIT Delhi and, Dr. S. Chattopadhyay from Kansas State University, USA. ))**

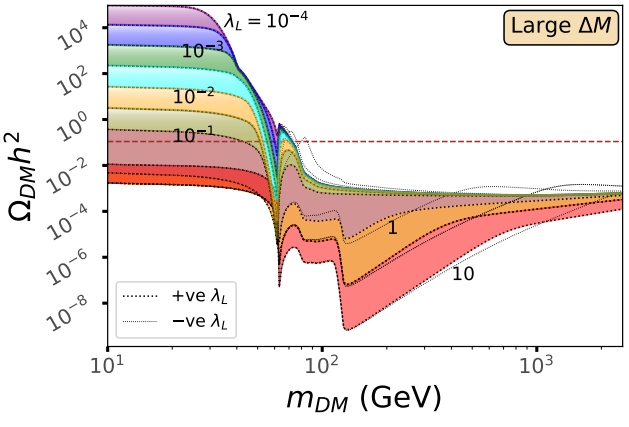
**FACt: FORTRAN toolbox for calculating fluctuations in atomic condensates**

We develop a FORTRAN code to compute fluctuations in atomic condensates (FACt) by solving the Bogoliubovde Gennes (BdG) equations for two component BoseEinstein condensate (TBEC) in quasi- two dimensions. The BdG equations are recast as matrix equations and solved self consistently. The code is suitable for handling quantum fluctuations as well as thermal fluctuations at temperatures below the critical point of BoseEinstein condensation. The code is versatile, and the ground state density profile and low energy excitation modes obtained from the code can be easily adapted to compute different properties of TBECs ground state energy, overlap integral, quasi particle amplitudes of BdG spectrum, dispersion relation and structure factor and other related experimental observables.

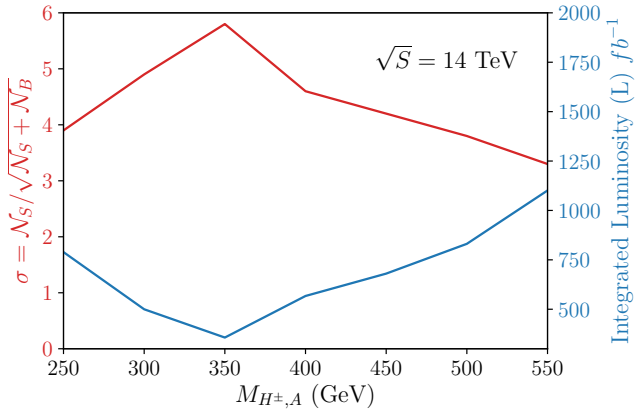
**(Arko Roy, Sukla Pal, D. Angom (work done in collaboration with Dr. P.Muruganandam from Department of Physics, Bharathidasan University, Tamil Nadu. And, Dr. Sandeep Gautam from IIT Ropar, Punjab))**

**Probing the inert doublet model using jet substructure with a multivariate analysis**

Challenging but phenomenologically interesting hierarchical mass spectrum of the inert doublet model is explored where relatively light dark matter along with much heavier scalar states can fully satisfy the constraints on the relic abundance and also fulfil other theoretical as well as collider and astrophysical bounds.




To probe this region of parameter space at the LHC, we propose a signal process that combines up to two large radius boosted jets along with substantial missing transverse momentum. Aided by our intuitive signal selection, we capture a hybrid signal contribution over the di-fatjet background. Substantiated by the sizable mass difference between the scalars, these boosted jets, originally produced from the hadronic decay of massive vector bosons, still carry the inherent footprint of their root. These features implanted inside the jet substructure can provide additional handles to deal with a large background involving QCD jets. We adopt a multivariate analysis using a boosted decision tree to provide a robust mechanism to explore the hierarchical scenario, which would bring almost the entire available parameter space well within reach of the 14 TeV LHC runs with high luminosity.

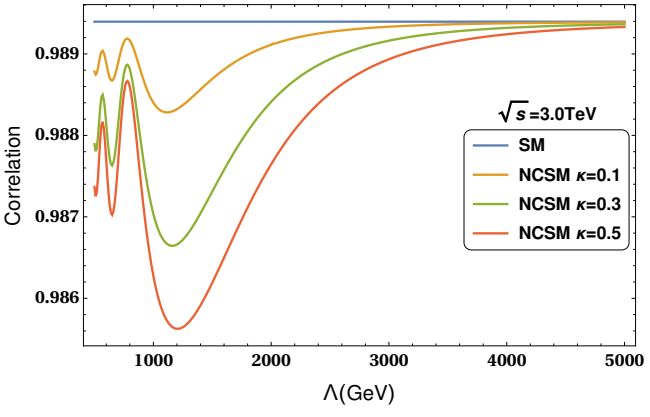



doi : https://doi.org/10.1103/PhysRevD.100.055040

**(A. Bhardwaj, P. Konar, S. Sadhukhan (work done in collaboration with T. Mandal (Uppsala Univ.)))**

**Inferring the covariant Θ-exact non-commutative coupling**

A novel non-minimal interaction of neutral right-handed fermion and abelian gauge field in the covariant Θ-exact non-commutative standard model (NCSM) which is invariant under Very Special Relativity (VSR) Lorentz subgroup, opens an avenue to study the top quark pair production at linear colliders. We also studied the intriguing mixing of the UV and the IR by invoking a specific structure of non-commutative anti-symmetric tensor $\Theta_{\mu\nu}$ which is invariant under translational T (2) VSR Lorentz subgroup.




doi : https://doi.org/10.1007/JHEP06(2019)108

**(J. Selvaganapathy, P. Konar (work done in collaboration with P. Das (BITS Pilani, Goa campus)))**

**Nonequilibrium electron relaxation in graphene.**

We apply memory function formalism to investigate nonequilibrium electron relaxation in graphene. Within the premises of two-temperature model (TTM), explicit expressions of the imaginary part of the memory function or generalized Drude scattering rate are obtained. In the DC limit and in equilibrium case where electron temperature is equal to phonon temperature, we reproduce the known results (i.e., scattering rate scales as T raise to power 4 when T is much less than Bloch-Gruneisen temperature and T linear when T is much greater that Bloch-Gruneisen temperature). We report several new results for scattering rate when electron temperature is not equatl to phonon temperature and we propose pump-probe spectroscopic experiments to verify these results.

doi : https://doi.org/10.1142/S0217979219501832

**(Luxmi Rani, Pankaj Bhalla, and Navinder Singh)**

# Atomic, Molecular and Optical Physics

**Photon statistics of twisted heralded single photons**

We study the correlation properties of single photons carrying orbital angular momentum (OAM) in a Hanbury Brown and Twiss (HBT) type experiment. We have characterized single photon sources obtained by pumping a nonlinear crystal with a laser beam carrying different OAM under same experimental conditions. For twisted heralded single photons carrying OAM, we calculate g(2)(0), a measurable parameter characterizing the quality of a single photon source, and observe an increment with the OAM of the single photon. The single photon behavior of the heralded photons is observed to be reducing with higher orders of their OAM. An OAM-dependent variation of the photon statistics will be relevant to quantum information experiments involving twisted heralded single photons.

doi : https://doi.org/10.1080/09500340.2019.1699180

**(N. Lal, A. Banerji, A. Biswas, A. Anwar and RP Singh)**

**Observing sub-Poissonian statistics of twisted single photons using oscilloscope**

Heralded single photon sources (HSPSs) from spontaneous parametric down-conversion are widely used as single photon sources. We study the photon number statistics of an HSPS carrying orbital angular momentum in our laboratory and observe the sub-Poissonian statistics using only photodetectors and an oscilloscope

doi : https://doi.org/10.1063/1.5109544

**(N. Lal, B. Shajilal, A. Anwar, C. Perumangatt and R. P. Singh)**

**Importance of considering natural sample luminescence sensitivity changes for the reliability of OSL ages**

Single Aliquot Regeneration (SAR) protocol is routinely used to estimate palaeodose for sediment samples. However, it was observed that significant changes in the OSL sensitivity occur during the read out of natural OSL and SAR protocol does not take into account these changes. It was suggested that if not corrected, this change of sensitivity would lead to substantive systematic offsets in ages based on conventional SAR protocol. To circumvent the issue of sensitivity change, a natural correction factor based SAR (NCF-SAR) protocol and a correction procedure was suggested by Singhvi et al., (2011) with an implicit but a reasonable assumption that the sensitivity of 110$^{\circ}$C TL peak of quartz correlates with the OSL sensitivity. Use of this correction resulted in reduced over-dispersion of paleodoses and helped resolve cases where natural signal was way above the regenerated signal.

As a logical extension of this work, sensitivity changes in the OSL from single grains of quartz were examined, during the read out of their natural OSL and their import on the accuracy and reliability of single grains based SAR ages. Toward this over 200 single grains each for 9 samples of diverse depositional environments were analysed and the NCF of each grain was estimated. NCF varied from 0.7 to 20 with $\sim$ 50 $\%$ in the range of 0.7-1.3. The results indicated that, i) the brighter grains (photon counts $>$ 1000 c/s) had NCF closer to 1, though significant outliers did exist, ii) the distribution of NCF was positively skewed with significant number of values greater than one, iii) the averaged single grain NCF values and the measured single aliquot NCF values were different, suggesting that in the case of single aliquots, sensitivity changes of dull grains also contribute, significantly.

doi : https://doi.org/10.1016/j.quageo.2019.101004

**(N. Chauhan and A. K. Singhvi)**

**Tunable ultraviolet vortex source based on a continuous-wave optical parametric oscillator**

We report a continuous-wave (cw) optical parametric oscillator (OPO) generating optical vortices tunable in the ultraviolet (UV). Based on MgO:sPPLT as the nonlinear crystal, the singly resonant OPO is pumped by a cw vortex beam in the green, and deploying intracavity sum-frequency generation (SFG) between the undepleted pump and the Gaussian resonant signal in the crystal of $BiB_3O_6$, it can generate optical vortices of order, $l_{uv}$ = 1 and 2, tunable across 332344 nm in the UV with a maximum power of 12 mW. Due to conservation of orbital angular momentum in the parametric process, the OPO also produces a non-resonant idler output beam in a vortex spatial profile of order, $l_i$=1 and 2, identical to the pump vortex, with the signal beam in Gaussian distribution. The idler vortex is tunable across 11721338 nm with maximum output power of 1.3 W.

This work was done in collaboration with Majid Ebrahim-Zadeh and his group from the Institute of Photonic Sciences, Barcelona

doi : https://doi.org/10.1364/OL.44.004694

**(V. Sharma, R. P. Singh and G. K. Samanta)**

**Frequencyconversion of vector vortex beams with spacevariant polarization in singlepass geometry**

Nonlinear frequency conversion processes depend on the polarization state of the interacting beams. On the other hand, vector vortex beams have spacevariant polarization in the transverse beam plane. In light of these two points, is it possible to do nonlinear frequency conversion of the vector vortex beam in single-pass geometry and retain the characteristics of the beam? To address this question, here, we report an experimental scheme for singlepass second harmonic generation (SHG) of vector vortex beams. Using an ultrafast Ti:Sapphire laser of pulse width $\sim$ 17fs and a set of spiral phase plates in a polarization based MachZehnder interferometer (MZI), we have generated vector vortex beams of order as high as $l_p$=12 at an average power of 860 mW. Using two contiguous bismuth borate crystals with the optic axis orthogonal to each other, we have frequency-doubled the nearIR vector vortex beam into visible vector vortex beam with order as high as $l_{sh}$=24. The maximum output power of the vector vortex beam of order, $l_{sh}$=2, is measured be as high as 20.5 mW at a single-pass SHG efficiency of 2.4$\%$. Controlling the delay in MZI, we have preserved the vector vortex nature of both the pump and frequencydoubled beams. Measurement on the mode purity confirms the generation of high quality vector vortex beams at pump and SHG wavelengths. This generic scheme can be used to generate vector vortex beams across the electromagnetic spectrum in all time scales, continuouswave to ultrafast.

doi : https://doi.org/10.1063/1.5111593

**(R. K. Saripalli, A. Ghosh, N. A. Chaitanya, and G. K. Samanta)**

**Experimental investigations on dating the last earthquake event using OSL signals of quartz from fault gouges**

Obtaining a reliable age of the latest seismic slip event along an active fault is important for seismic hazard assessment. Here, we observe changes in the optically stimulated luminescence (OSL) signal of quartz crystals due to frictional heating in artificial fault gouges (comprising a mixture of quartz grains and Ca-bentonite powder). The fault gouge was deformed using a high-velocity rotary-shear apparatus at room temperature and room humidity. At a seismic slip rate of 1.31ms$^{-1}$, intense slip localization occurred along a very thin layer ($\sim$ 300$\mu$m thick) within the simulated fault zones (1mm thick). The estimated temperature of the slip-localized layer (SLL) increased by $\sim$ 475$^{\circ}$C from frictional heating. The quartz OSL signals of the gouges were fully reset, most noticeably for the SLL. In contrast, there was rare slip-localization at subseismic slip rates (0.06-0.001ms$^{-1}$), for which the estimated temperature rise in the SLL was $\sim$120$^{\circ}$C; hence, the quartz OSL signal was not reset under this condition. The results suggest that quartz OSL dating can be used to constrain the age of the latest seismic event in natural quartz-bearing fault zones where a SLL occurs.

This work is in collaboration with J.H. Kim, J. H. Ree from Korea University, Seoul, South Korea; J. H Choi from Korea Basic Science Institute, South Korea; T. Hirose from Kochi Institute for Core Sample Research, Japan and M. Kitamura from Geological Survey of Japan, Japan

doi : https://doi.org/10.1016/j.tecto.2019.228191

**(N. Chauhan)**

**Controlled generation of array beams of higher order orbital angular momentum and study of their frequencydoubling characteristics**

We report on a simple and compact experimental scheme to generate highpower, ultrafast, higherorder vortexarray beams. Simply by using a dielectric microlensarray (MLA) and a plano-convex lens, we have generated arraybeams carrying the spatial property of the input beam. Considering the MLA as a 2D sinusoidal phase-grating, we have numerically calculated the intensity pattern of the arraybeams in close agreement with the experimental results. Using vortex beams of order as high as l=6, we have generated vortex array-beam with individual vortices of orders up to l=6. We have also theoretically derived the parameters controlling the intensity pattern, size, and the array-pitch and verified experimentally. The single-pass frequencydoubling of vortex array at 1064nm in a 1.2mm long BiBO crystal produced green vortex-array of order, $l_sh$=12, twice the order of pump beam. Using lenses of different focal lengths, we have observed the vortexarrays of all orders to follow a focusing dependent conversion similar to the Gaussian beam. The maximum power of the green vortexarray is measured to be 138mW at a single-pass efficiency as high as $\sim$ 3.65%. This generic experimental scheme can be used to generate the array beams of desired spatial intensity profile across a wide wavelength range by simply changing the spatial profile of the input beam.

doi : https://doi.org/10.1038/s41598-019-47403-1

**(B. S. Harshith and G. K. Samanta)**

**Surface paleothermometry using low temperature thermoluminescence of feldspar**

Thermoluminescence (TL) of feldspar is investigated for its potential to extract temperature histories experienced by rocks exposed at Earths surface. TL signals from feldspar observed in the laboratory arise from the release of trapped electrons from a continuous distribution of trapping energies that have range of thermal stabilities. The distribution of trapping energies, or thermal stabilities, is such that the lifetime of trapped electrons at room temperature ranges from less than a year to several billion years. Shorter lifetimes are associated with low temperature TL signals, or peaks, and longer lifetimes are associated with high temperature TL signals. Here we show that trapping energies associated with shorter lifetimes, or lower temperature TL signals (i.e., between 200 $^{\circ}$C and 250 $^{\circ}$C), are sensitive to temperature fluctuations occurring at Earths surface over geological timescales. Furthermore, we show that it is possible to reconstruct past surface temperature histories in terrestrial settings by exploiting the continuous distribution of trapping energies. The potential of this method is first tested through theoretical experiments, in which a periodic temperature history is applied to a kinetic model that encapsulates the kinetic characteristics of TL thermometry. We then use a Bayesian approach to invert TL measurements into temperature histories of rocks, assuming that past temperature variations follow the observed $\delta^{18}$O anomalies. Finally, we test the approach on two samples collected at the Mer de Glace (Mont Blanc massif, European Alps) and find similar temperature histories for both samples. Our results show that TL of feldspar may be used as a paleo-thermometer.

This work is in collaboration with Dr. R. H. Biswas, F. Herman, G.E. King and B. Lehmann from University of Lausanne, Switzerland

doi : https://doi.org/10.5194/cp-2019-173

**(A. K. Singhvi)**

**Aeolian dune accommodation space for Holocene Wadi Channel Avulsion Strata, Wahiba Dune Field, Oman**

Geomorphic evolution of the Wahiba Dune Field, Oman, during the Quaternary has occurred within a set of boundary conditions that include climatic forcing of fluvial, aeolian and eustatic cycles within an active tectonic basin. Because of basin down-warping and sediment transport into the basin, evolution of the geomorphic surface has been accompanied by the generation of a distinctive stratigraphic record. The coupled geomorphic and stratigraphic record of the northeastern portion of the dune field illustrates wadi-aeolian interactions, in which a channel avulsion, likely initiated during a flood, scoured through the interdune corridor between linear dunes. Interdune outcrops (7m thick) consist of a lower interval interpreted as deposited by ephemeral fluvial flow, but an upper interval consists of six fining-upward units, each of which is interpreted to represent a flood event that culminated in ponding followed by desiccation. Luminescence dating indicates that the channel remained open for 23ka during the Holocene, but ground-penetrating radar imaging shows that dunes encroached into the channel between floods and suggests that the transition from ephemeral flow to ponding resulted from dune damming. Maximum channel width and length are unknown, but width was greater than the current interdune area, and a speculative extended channel course is identified. Subsequently, interdune strata and linear dunes were buried by crescentic dunes sourced by an influx of sand with wadi affinity. The resultant complex stratigraphic architecture illustrates the role of existing surface topography in providing local geomorphic accommodation space for short-lived, concentrated patterns of sedimentation. This work is in collaboration with Gary Kocurek from University of Texas, USA; Robin Westerman from Yorkshire, UK; Caroline Hern from Shell International Exploration & Production, Houston, USA; Dominic Tatum from Institute for GeoEnergy Engineering, Edinburgh, UK

doi : https://doi.org/10.1016/j.sedgeo.2020.105612

**(H.M. Rajapara and A. K. Singhvi)**

**Singlepass, secondharmonic generation of highpower, ultrafast midIR $Cr^{2+}$:ZnS laser at 2360 nm**

We report on a compact and simple ultrafast source producing tunable radiation in the near-IR wavelength range. Based on singlepass frequency doubling of an ultrafast $Cr^{2+}$: ZnS laser at 2360 nm with pulse width of 43 fs at a repetition rate of 80 MHz in MgO:PPLN crystal, the source produces maximum average output power of $\sim$ 2.43 W tunable across 11371200 nm with a maximum single-pass conversion efficiency as high as 65%. Without use of any pulse compression technique, the source produces output pulses in Gaussian shape with measured pulse width of $\sim$ 60fs and spectral width of 39 nm centered at 1180 nm corresponding to a time-bandwidth product of 0.5. The output beam has a Gaussian spatial profile with measured M2¡1.32 and a peak to peak power fluctuation of 3% over 2 h. Using MgO:PPLN crystal of two different lengths, 1 mm and 2 mm, we have observed that the optimum second harmonic generation efficiency of an ultrafast pulse laser, even in the presence of temporal walk off, appears in the low pump focusing condition.

doi : https://doi.org/10.1364/OL.44.003522

**(A. Ghosh, D. Yadav, and G. K. Samanta)**

**Controlled generation of vortex and vortex dipole from a Gaussian pumped optical parametric oscillator**

We report on direct generation of optical vortices from a continuous-wave (cw), Gaussian beam pumped doubly resonating optical parametric oscillator (DRO). Using a 30-mm long MgO doped periodically poled lithium tantalate (MgO:sPPLT) crystal based DRO, pumped in the green by a frequencydoubled Yb-fiber laser in Gaussian spatial profile we have generated signal and idler beams in vortex mode of order, l = 1, tunable across 9701178 nm. Controlling the overlap between the Gaussian pump beam with the fundamental cavity mode of the resonant signal and idler beams of the DRO through the tilt of the pump beam and/or the cavity mirror in transverse plane, we have generated both signal and idler beams in vortex and vortex dipole spatial profiles. Using the theoretical formalism for the vortex beam generation through the superposition of two Gaussian beams we have numerically calculated the spatial profile of the generated beam in close agreement with our experiment results. The generic experimental scheme can be used to generate optical vortex across the electromagnetic spectrum and in all time scales (cw to ultrafast) using suitable OPO.

doi : https://doi.org/10.1364/OE.27.018123

**(V. Sharma, A. Aadhi, and G. K. Samanta)**

**Tunable vectorvortex beam optical parametric oscillator**

Vectorvortex beams, having both phase and polarization singularities, are of great interest for a variety of applications. Generally, such beams are produced through systematic control of phase and polarization of the laser beam, typically external to the source. However, efforts have been made to generate vectorvortex beams directly from the laser source. Given the operation of the laser at discrete wavelengths, vector-vortices are generated with limited or no wavelength tunability. Here, we report an experimental scheme for the direct generation of vectorvortex beams. Exploiting the orbital angular momentum conservation and the broad wavelength versatility of an optical parametric oscillator, we systematically control the polarization of the resonant beam using a pair of intracavity quarter-wave plates to generate coherent vector-vortex beam tunable across 964990nm, with output states represented on the higherorder Poincar sphere. The generic experimental scheme paves the way for new sources of structured beams in any wavelength range across the optical spectrum and in all timescales from continuous wave to ultrafast regime.

This work was done in collaboration with Majid EbrahimZadeh and his group from the Institute of Photonic Sciences, Barcelona

doi : https://doi.org/10.1038/s41598-019-46016-y

**(V. Sharma, A. Aadhi, and G. K. Samanta)**

**Controlling the biphoton orbital angular momentum eigenmodes using asymmetric pump vortex beam**

We report on controlling the biphoton orbital angular momentum (OAM) eigenmodes in the spontaneous parametric down conversion process by simply adjusting the asymmetry of the pump vortex beam. Adjusting the optic axis of the spiral phase plate of phase winding corresponding to OAM mode, l, with respect to the beam propagation axis, we have transformed a Gaussian beam into an asymmetric vortex beam with OAM modes, l, l1, l2...0 with different weightages. Pumping the nonlinear crystal with such asymmetric vortices and controlling their asymmetry we have tailored the spiral spectrum of the biphoton OAM eigenmodes. Calculation of azimuthal Schmidt number of the biphotons showed an increase in the spiral bandwidth of the OAM eigenmodes and hence the dimensionality of the system. Although we have restricted our study to show the increase in spiral bandwidth of the biphotons by simply controlling the asymmetry of the pump vortices, the dimensionality of the bi-photon states can be enhanced further by manipulating the pump beam size and crystal length.

doi : https://doi.org/10.1088/2040-8986/ab1460

**(M. V. Jabir, A. Anwar, and G. K. Samanta)**

**Relativistic effects in the determination of electric dipole moments and polarizabilities of heteronuclear alkali dimers**

We analyzed the molecular electric dipole moments (PDMs) and static electric dipole polarizabilities of heteronuclear alkali dimers in their ground states by employing coupled-cluster theory, both in the nonrelativistic and fourcomponent relativistic frameworks. The roles of the electron correlations as well as the relativistic effects were demonstrated by studying them at different levels of theory. We compared our results with the previous non-relativistic calculations, some of which include lower-order relativistic corrections, as well as with the experimental values, wherever available. We found that the PDMs are sensitive to the relativistic effects, as compared to polarizabilities. We showed that consideration of the relativistic values of PDMs improves significantly the isotropic Van der Waals $C_6$ coefficients of the investigated alkali dimers over the previously reported non-relativistic calculations. The dependence of dipole polarizabilites on molecular volume was also illustrated.

doi : https://doi.org/10.1103/PhysRevA.101.012511

**(R. Mitra, V. S. Prasannaa and B. K. Sahoo)**

**Accurate determination of spectroscopy properties of triply ionized tin isotopes**

We investigated energies, magnetic dipole hyperfine structure constants ($A_{hyf}$ ) and electric dipole (E1) matrix elements of a number of lowlying states of the triply ionized tin ($Sn^{3+}$) by employing relativistic coupledcluster theory. Contributions from the Breit interaction and lower-order quantum electrodynamics (QED) effects in determination of above quantities were also given explicitly. These higher-order relativistic effects were found to be important for accurate evaluation of energies, while only QED contributions were seen to be contributing significantly to the determination of $A_{hyf}$ values. Our theoretical results for energies were in agreement with one of the measurements but show significant differences for some states with another measurement. Reported $A_{hyf}$ will be useful in guiding measurements of hyperfine levels in the stable isotopes of $Sn^{3+}$. The calculated E1 matrix elements were further used to estimate oscillator strengths, transition probabilities, and dipole polarizabilities ($\alpha$) of many states. Large discrepancies between present results and previous calculations of oscillator strengths and transition probabilities were observed among a number of states. The estimated $\alpha$ values will be useful for carrying out high precision measurements using $Sn^{3+}$ ion in future experiments.

This work was carried out in collaboration with M. Kaur, N. Nakra and B.Arora of Department of Physics, Guru Nanak Dev University, Punjab, India, and C. B. Li of Wuhan Institute of Physics and Mathematics, Wuhan, China.

doi : https://doi.org/10.1088/1361-6455/ab68b7

**(B. K. Sahoo)**

**Optical lattice based method for precise measurements of atomic parity violation**

We proposed a method for measuring parity violation in neutral atoms. It was an adaptation of a seminal work by Fortson [Phys. Rev. Lett. 70, 2383 (1993)], proposing a scheme for a single trapped ion. In our version, a large sample of neutral atoms should be localized in an optical lattice overlapping a grid of detection sites, all tailored as the single site in Fortsons work. The methodology was of general applicability, but as an example, we estimated the achievable signal in an experiment probing a nuclear spin independent parity violation on the line 6s $^2S_{1/2}$-5d $^2D_{3/2}$ in $^{133}$Cs. The projected result was based on realistic parameters and ab initio calculations of transition amplitudes, using the relativistic coupled-cluster method. The final result was a predicted spectroscopic signature, evidencing parity violation, of the order of 1 Hz, for a sample of 108 atoms. We showed that a total interrogation time of 30 000 s should, together with existing theoretical data, suffice for achieving a precision in the determination of the weak charge of Cs of the order of 0.1% a sensitivity surpassing previously reported determinations by at least a factor of 5.

This work was carried out in collaboration with A. Kastberg of Institute de Physique de Nice, Universit Cte dAzur, CNRS, 06108 Nice, France, T. Aoki of Institute of Physics, Graduate School of Arts and Sciences, The University of Tokyo, Tokyo 1538902, Japan, Y. Sakemi of Center for Nuclear Study, The University of Tokyo, Wako 1130033, Japan and B. P. Das of Department of Physics, Tokyo Institute of Technology, 2-12-1 Ookayama Meguro-ku, Tokyo 1528550, Japan.

doi : https://doi.org/10.1103/PhysRevA.100.050101

**(B. K. Sahoo)**

**Analytic Response Relativistic CoupledCluster Theory**

To provide solution to the increasing demand for accurate calculation of isotope shifts of atomic systems for fundamental and nuclear structure research, an analytic energy derivative approach was

presented in the relativistic coupled-cluster theory framework to determine the atomic field shift and mass shift factors. This approach allowed us to determine the expectation values of atomic operators, overcoming fundamental problems that are present in existing atomic physics methods, i.e. it satisfies the Hellmann Feynman theorem, does not involve any non-terminating series, and is free from choice of any perturbative parameter. High-precision isotope-shift measurements of $^{104-127}$In were also performed in the 246.8 nm (5p $^2P_{3/2} \rightarrow$ 9s $^2S_{1/2}$) and 246.0 nm (5p $^2P_{1/2} \rightarrow$ 8s $^2S_{1/2}$) transitions to test our theoretical results. An excellent agreement between the theoretical and measured values was found, which is known to be challenging in multi-electron atoms.The calculated atomic factors allowed an accurate determination of the nuclear charge radii of the ground and isomeric states of the $^{104-127}$In isotopes,providing an isotone-independent comparison of the absolute charge radii.

This work was carried out in collaboration with A. R. Vernon, R.F. Garcia Ruiz, C.L. Binnersley, M. Bissell, J. Billowes, M. L. Bissell, T. E. Cocolios,G. J. Farooq-Smith, K. T. Flanagan, W. Gins, R. P. de Groote,A. Koszorus, G. Neyens, K. M. Lynch, F. Parnefjord-Gustafsson, C. M. Ricketts, K. D. A. Wendt, S. G. Wilkins and X. F. Yang of ISOLDE facility of CERN.

doi : https://doi.org/10.1088/1367-2630/ab66dd

**(B.K.Sahoo)**

**Roles of electron correlation effects for the accurate determination of g$_j$ factors of low-lying states of $^{113}$Cd$^+$**

We investigated roles of electron correlation effects in the determination of gj factors of the ns $^2S_{1/2}$ (n=5,6,7), np $^2P_{1/2,3/2}$ (n=5,6), 5d $^2D_{3/2,5/2}$, and 4f $^2F_{5/2,7/2}$ states of the singly ionized cadmium ($Cd^+$) ion. Single and double excited configurations along with important valence triple excited configurations through relativistic coupledcluster (RCC) theory were taken into account for incorporating electron correlation effects in our calculations. We found significant contributions from the triples to the lower S and P states for attaining high accuracy results. The contributions of Breit interaction and lowerorder quantum electrodynamics effects, such as vacuum polarization and selfenergy corrections, were also estimated using the RCC theory and are quoted explicitly. In addition, we presented energies of the aforementioned states from our calculations and compared them with the experimental results to validate g$_j$ values. Using the g$_j$ factor of the ground state, systematical shift due to the Zeeman effect in the microwave clock frequency of the —5s $\sim$ $^2S_{1/2}$ , F = 0, m$_F$ = 0$\rangle \leftrightarrow$ —5s $\sim$ $^2S_{1/2}$ , F = 1, m$_F$ = 0$\rangle$ transition in $^{113}$Cd$^+$ ion was estimated

This work was done in collaboration with J. Z. Han, J. W. Zhang and L. J. Wang of Department of Physics, Tsinghua University, Beijing 100084, China, and Yan-mei Yu of Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China,

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**(B. K. Sahoo)**

**Probing New Physics Beyond the Standard Model by Studying Electric Dipole Moment of $^{129}$Xe**

We reported the results of our theoretical studies of the time-reversal and parity violating electric dipole moment (EDM) of $^{129}$Xe arising from the nuclear Schiff moment (NSM) and the electronnucleus tensorpseudotensor (TPT) interaction based on the selfconsistent and the normal relativistic coupled-cluster methods. The important manybody effects were highlighted and their contributions were explicitly presented. The uncertainties in the calculations of the correlation and relativistic effects were determined by estimating the contributions of the triples excitations and the Breit interaction, respectively, which together amounted to about 0.7% for the NSM and 0.2% for the T-PT interactions. The results of our present work in combination with improved experimental limits for $^{129}$Xe EDM in the future would tighten the constraints on the hadronic CP violating quantities, and this could provide important insights into new physics beyond the standard model of elementary particles.

This work was carried out in collaboration with A. Sakurai and B. P. Das of Department of Physics, Tokyo Institute of Technology, 2121 Ookayama Meguroku, Tokyo 152-8550, Japan, and K. Asahi of RIKEN Nishina Center, 21 Hirosawa, Wakoshi, Saitama 3510198, Japan

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**(B. K. Sahoo)**

**Application of relativistic coupled cluster theory to elastic scattering of electrons from confined Ca atoms**

We carried out theoretical investigations of electron correlation effects on the atomic properties of the Ca atom trapped inside an attractive spherically symmetric potential well of an endohedral fullerene $C_{60}$ cluster. Relativistic coupledcluster (RCC) theory was employed to obtain electron correlation energy, ionization potential and dipole polarizability of this atom. Our results were compared with the reported calculations employing multiconfiguration HartreeFock (MCHF) method in Phys. Rev. A 93, 022512 (2016). We found trends in correlation energy with respect to the potential depth are same, but magnitudes were very large in the relativistic calculations. We also determined the differential and total crosssections for elastic scattering of electrons from the free and confined Ca atoms to demonstrate role of potential depth in these properties.

This work was carried out in collaboration with S. Bharti, L. Sharma, P. Malkar and R. Srivastava of Department of Physics, Indian Institute of Technology Roorkee, Roorkee 247667, India

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**(B. K. Sahoo)**

**Highprecision determination of Lorentzsymmetryviolating parameters in Ca$^+$**

Highprecision calculations of local Lorentz invariance (LLI) violating parameters of the 3d $^2D_{3/2;5/2}$ states in $Ca^+$ was reported. We

employed three variants of the relativistic coupledcluster (RCC) theory to determine these coefficients by gradually including electron correlation effects through the single, double and triple excitation determinants from the DiracHartreeFock wave function. A precise estimate of the energy shift due to LLI violation depends on accurate evaluations of the expectation values of the square of the momentum operator ($\langle p^2 \rangle$) and a second rank tensor ($\langle T_0^{(2)} \rangle$). It was found that the $\langle T_0^{(2)} \rangle$ values converge smoothly with the systematic inclusion of higher-order correlation effects in an expectation value evaluation approach, however that is not the case for $\langle p^2 \rangle$. Similar trends were also observed in the finite-field approach. To circumvent these problems, we determined $\langle p^2 \rangle$ values very precisely by developing and applying an analytic gradient approach in the RCC framework. Corrections due to the Breit and quantum electrodynamics interactions were also estimated. Further, these calculations were validated by evaluating the energies and the quadrupole moments of the above states at different levels of approximations.

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**(B. K. Sahoo)**

### Nanoparticles induced optical signal enhancement in LIBS

The nanoparticles induced optical signal enhancement has been studied using LIBS technique. To investigate the laser energies dependence on the enhancement, we recorded the NELIBS spectra at 0.8 mg/ml as function of laser energy in the gate delay at 1000ns, gate width at 2000ns. The peak height ratio between NELIBS and LIBS emission intensity of Cu I 521.82 nm line profile at different laser energies is analyzed and shown in figure. The trend is increasing as function of laser energy. This is clear that the increasing trend is due to nanoparticles and thus there is a unique mechanism through which nanoparticles coupled to laser field which contribute in signal enhancement. There are many models have been proposed but for complete study more experimental investigations will be required. In this case study, we attempted to observed the enhancement as function of laser energy, gate delay and concentrations.

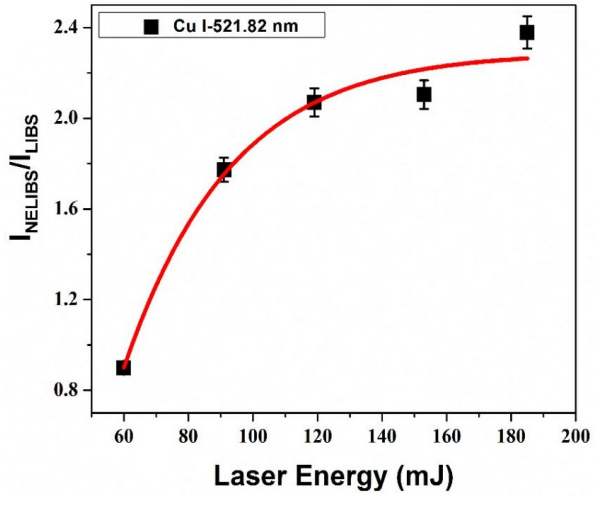


Figure 1: Ratio between NELIBS and LIBS intensity at Cu I 521.82 nm wavelength plotted as a function of laser energy at 0.8 mg/ml Al NPs concentration. Acquisition conditions: gate delay 1000 ns, gate width 2000 ns

doi : https://doi.org/10.1007/978-981-15-0202-6_7

**(E. Nageswara Rao, S. Soumyashree, P. Kumar, P. Chandravanshi, S.B. Banerjee, K. P. Subramanian, R. K. Kushawaha)**

### New femtosecond laser laboratory in PRL

In this year, the commissioning of new femtosecond laser lab has been performed. This lab is for conducting research on ultrafast science.

Figure 2: Femtosecond Laser Laboratory, AMOPH division, PRL

In atomic and molecular system, the nuclear dynamics is in picosecond ($10^{-12}$s) to femtosecond ($10^{-15}$s) time scale and electron dynamics is in attosecond ($10^{-18}$s) time scale. The science at these time scale is known as ultrafast science. As measurement at this short time scale is very challenging, a lab should have vibration noise dampers, controlled temperature and humidity environment and cleanroom. This lab is unique in India in terms of facilities. The vibration control has been performed by “anti-vibration floor isolation” and optical tables. The whole lab is cleanroom of ISO 7 grade. In this lab, we have developed the pump-probe setup and Velocity Map Imaging Spectrometer.

**(P. Madhusudhan, P. Bhardwaj, R. Das, S. Soumyashree, P. Chandravanshi, N. Vinitha, P. Kumar, S.B. Banerjee, K.P. Subramanian, R. K Kushawaha)**

### Residue from vacuum ultraviolet irradiation of benzene ices: Insights into the physical structure of astrophysical dust

We have irradiated benzene ices that are formed at 4 K on a cold interstellar dust analog to vacuum ultraviolet (9 eV) irradiation for periods lasting from several hours to nearly a day, after which the irradiated ice was warmed to room temperature. Vacuum ultraviolet photoabsorption spectra of the aromatic residue left at room temperature were recorded and showed the synthesis of

benzene derivatives. The residue was also imaged using an electron microscope and revealed crystals of various sizes and shapes. The result of our experiments suggest such geometrically shaped dust particles may be a key be component of interstellar dust.

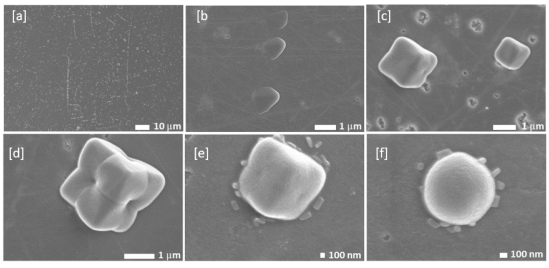


Figure-3: Shows the FE-SEM images of (a) particles left after irradiation for nearly 9 hours on top of the LiF window, (b) flakes, (c & d) cubes, (e) cube surrounded by rod shaped particles and (f) spherical particle surrounded by small particles

This work was carried out using the NSRRC beamtime grant in the year 2019

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**(K K Rahul, S Karthik, J K Meka, P Janardhan, A Bhardwaj, B Sivaraman)**

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8. Harish, S. Vijayan and N. Mangold, 2020, *"Degana crater, Mars: Evidence for fluvial and glacial landforms on a volcanic dome"*, Proceedings of $51^{st}$ Lunar and Planetary Science Conference, Abstract no. 1221.
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10. Rani A., A. Basu Sarbadhikari, R. K. Sinha, S. Karunatillake, G. Komatsu and A. Bates, 2020, *"Mounds and ridges inside a floor-fractured crater in Central Eastern Arabia Terra"*, $51^{st}$ Lunar and Planetary Science Conference, Houston, Texas, Abstract no. 1955.
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# Publications

# Books Edited / Review Articles / Other Publications

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2. Ganguly Jibamitra , Singhvi A.K.(Ed), 2019, *"Meghnad Saha: His Science and Persona through Selected Letters and Writings"*, IIndian National Science Academy, DelhiReleased on October 4, 2019
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1. Bhattacharya, S., K. Pande, A. Kumar, O. Kingson, and J.S. Ray, 2020, *"Timing of Formation and Obduction of the Andaman Ophiolite"*, In: Ray JS, M Radhakrishna (eds) The Andaman Islands and Adjoining Offshore, Geology, Tectonics and Palaeoclimate, Springerp. 19-42, doi:https://doi.org/10.1007/978-3-030-39843-9_2
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3. Deshpande, R.D., 2019, *"Isotope Hydrology, Water Futures of India-Status of Science and Technology"*, in P.P. Mujumdar and V.M. Tiwari (Eds), Indian National Science Academy, IISc Press, Bangalurup. 117-144.
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2. Sarkhel, S., S. Mondal, R. Sekar, D. Chakrabarty, and S. Sridharan, 2019, *"A review on the upper atmospheric sodium observations from India: Insights"*, Advances in Space Research, v.v. 63, p. 3568-3585

# Papers Presented in National/ International Conferences

**International Conferences**

Oral Presentations: 23

Poster Presentations: 32

1. Arya, R., “Primordial Black Holes Generation from Warm Inflation”, International Conference on Gravitation and Cosmology, 10-13 December, 2019
2. Arya, R., “Primordial Black Holes from Warm Inflation”, International Workshop on Frontiers of High Energy Physics, 14-17 October 2019
3. Arya,R., “Creation of Primordial Black Holes from Warm Inflation”, International Workshop on Astrophysics and Cosmology, ICC, Charusat, 20-26 December 2019
4. Sahoo,S., “Analysis of $\mathrm{B} \to \mathrm{D}\ell\nu_\ell$ decay modes”, International Workshop on Frontiers of High Energy Physics, 14-17 October 2019
5. Sahoo,S., “Testing role of new physics in $b \to c\ell\bar{\nu}_\ell$ transitions”, Indo-US Workshop on Anomalies 2019, 18-20 July 2019
6. D. Ray, D. Garg and A. Sengupta, “Micro-Raman studies of naturally occurring feldspar, shocked feldspar and maskelynite: Implications for in-situ mineralogy and planetary exploration”, CLEO 2019 - Laser Science to Photonic Application, San Jose, California, USA, 5-10 May 2019
7. K. Acharyya, “Formation of Water in the star-forming regions of low metallicity galaxies”, International Conference on Infrared Astronomy and Astrophysical Dust (IRAAD), IUCAA, Pune, 22-25 October, 2019
8. K. Durga Prasad, C. Kumar, S. K. Mishra, P. K. S. Reddy, J. Kumar, V. Sheel, S. A. Haider and A. Bhardwaj, “A Small Instrument Suite for Local Meteorology onboard Future Balloon Mission to Venus”, $16^{th}$ Asia Oceania Geosciences Society (AOGS), Singapore, 28 Jul to 2 Aug, 2019
9. M. Shanmugam, “Alpha Particle X-ray Spectrometer onboard Chandrayaan-2 Rover”, $16^{th}$ Asia Oceania Geosciences Society (AOGS), Singapore, 28 Jul to 2 Aug, 2019
10. M. Shanmugam, “Solar X-ray Monitor onboard Chandrayaan-2 Orbiter”, $16^{th}$ Asia Oceania Geosciences Society (AOGS), Singapore, 28 Jul to 2 Aug, 2019
11. P. K. S. Reddy, C. Kumar, K. Durga Prasad and V. Sheel, “A 3D Surface Thermophysical Model for Mars Implications for Mars Landing Missions”, COMSOL International Conference, Bangalore, 27-29 November 2019
12. S. Baliyan H. Moitra, S. Sarkar, D. Ray, D. K. Panda, A. D. Shukla, S. Bhattacharya and S. Ghosh, “Mineralogy and Spectroscopy (VNIR and FTIR) of Mukundpura CM2: More insights into aqueous activity and post accretion history”, $82^{nd}$ Annual Meeting of the Meteoritical Society, 7-12 July 2019
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14. V. Sheel and A. Modak, “Effect of Dust on Martian Ozone”, $16^{th}$ Asia Oceania Geosciences Society (AOGS), Singapore, 28 Jul to 2 Aug, 2019
15. V. Sheel and J. P. Pabari, “Radio Occultation Experiment for Probing Planetary Ionospheres”, 2019 URSI Asia Pacific Radio Science Conference, India Habitat Centre, New Delhi, India, 09-15 March, 2019
16. Laskar, F. I., N. M. Pedatella, M. Codrescu, R. Eastes, and D. Pallamraju, “Investigation of thermospheric composition and dynamics using GOLD satellite mission: A data assimilation approach”, AGU Fall Meeting, 2019
17. D. Pallamraju, “Space Weather: Science and Applications”, Inaugural lecture in Short Course on Space Weather organized by UN-CSSTEAP hosted at the Physical Research Laboratory, Ahmedabad, 14 - 27 November 2019
18. Duggirala Pallamraju, Ravindra P. Singh, Subir Mandal, Deepak K. Karan, and Fazlul I. Laskar, “Investigations on upper atmospheric variability on a global scale due to the influence of solar forcing from above and vertical coupling from below”, VarSITI Closing Symposium, Sofia, Bulgaria, 10 - 14 June 2019
19. William Ward, Franz-Josef Lbken, Annika Seppala, Bernd Funke, Alexei Krivolutsky, Tom Woods, Takuji Nakamura, Claudia Stolle, Erdal Yigit, Jan Lastovicka, Dan Marsh, Duggirala Pallamraju, and Stan Solomon, “Role Of the Sun and the Middle atmosphere/thermosphere/ionosphere In Climate (ROSMIC): A Retrospective and Prospective View”, VarSITI Closing Symposium, Sofia, Bulgaria, 10 - 14 June 2019
20. Subir Mandal, D. Pallamraju, D. K. Karan, K. A. Phadke, R. P. Singh, and P. Suryawanshi, “Information on gravity wave propagation characteristics in the upper atmosphere as obtained using Digisonde measurements”, SuperDARN workshop, Fujiyoshida, Yamanashi, Japan, 2 - 7 June 2019
21. Priyanka Ghosh and Som Sharma, “Study of Vertical Wavenumber Spectra During Sudden Stratospheric Warmings over India”, 16th annual meeting of the Asia Oceania

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22. Som Sharma, Prashant Kumar, Priyanka Ghosh, Niranjan Kumar Kondapalli, Rajesh Vaishnav, "Is Extreme Rainfall Event Influences the Mesospheric Features?", 16th annual meeting of the Asia Oceania Geosciences Society (AOGS), Singapore, 28 July-02 August, 2019
23. R. Bhattacharyya, "On three dimensional nulls", $5^{th}$ Asia Pacific Solar Physics Meeting (APSPM), IIUCAA Pune, 3-7 February, 2020
24. R. Sarkar, N. Gopalswamy, and N. Srivastava, "On the prediction of magnetic field vectors of interplanetary coronal mass ejections", $5^{th}$ Asia Pacific Solar Physics Meeting (APSPM), IIUCAA Pune, 3-7 February, 2020
25. K. Bora and R. Bhattacharyya, "Development of numerical model based on Hall Magnetohydrodynamics", $5^{th}$ Asia Pacific Solar Physics Meeting (APSPM), IIUCAA Pune, 3-7 February, 2020
26. K. Upadhyay, B. Joshi, P. K. Mitra, R. Bhattacharyya, D. Oberoi, and C. Monstein, "Solar radio observation using CALLISTO at the USO/PRL", IEEE International microwave and RF conference (IMaRC), IIT Bombay, 13-15 December, 2019
27. H. Kumar and B. Kumar, "Magnetic-jerk driven seismic emissions in the solar active region NOAA 11158 observed during a large flare", IRIS-10 International Meeting, Christ University, Bangalore, 4-8 November, 2019
28. S. S. Nayak and R. Bhattacharyya, "Three-dimensional null as a self-organised state", IRIS-10 International Meeting, Christ University, Bangalore, 4-8 November, 2019
29. C.R. Sangeetha, B. Ravindra, D. Tripathy, and B. Kumar, "Magnetic and kinetic helicity changes during large solar flares", IRIS-10 International Meeting, Christ University, Bangalore, 4-8 November, 2019
30. P. K. Mitra and B. Joshi, "Preflare processes, flux rope Activation, large-scale eruption, and associated X-class flare from the active region NOAA 11875", IRIS-10 International Meeting, Christ University, Bangalore, 4-8 November, 2019
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33. P. K. Mitra, B. Joshi and M. Syed Ibrahim, "Magnetic field configuration and energy release in an unconventional circular ribbon eruptive flare", $5^{th}$ Asia Pacific Solar Physics Meeting (APSPM), IIUCAA Pune, 3-7 February, 2020
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36. S. S. Nayak and R. Bhattacharyya, "Spontaneous generation of three-dimensional magnetic null point", XXXI Canary Islands Winter School on Computational Astrophysics, Tenerife, Spain, 18-29 November, 2019
37. R. Sarkar, N. Gopalswamy and N. Srivastava, "Observationally Constrained Analytical Model for Predicting Magnetic Field Vectors of ICMEs at 1 AU", International Space Weather Initiative Workshop 2019, International Center for Theoretical Physics, Trieste, Italy, 20-24 May, 2019
38. Singh, R. P. and D. Pallamraju, "Vertical coupling in the MLT region using long-term ground-based measurements of O2(0-1) and OH(6-2) nightglow emission intensity and temperature from Mount Abu (24.6$^{\circ}$N, 72.8$^{\circ}$E)", EGU General Assembly 2019, Vienna, Austria, 7-12 April 2019
39. B. Sivaraman, "Astrophysical Dust Fibres and Crystals", International Conference on the Infrared Astronomy and the Astrophysical Dust(IRAAD), Pune, 22 25 October,2019
40. Banerji, U.S., R. Bhushan and S. Pandey, "Evidence of land-sea interaction during mid-late Holocene from sedimentary records, western India", Young Earth Scientist Network German Chapter 2019, held at Berlin, Germany, September 9 - 13, 2019
41. Bhattu, D., J.G. Slowik1,I. El Haddad, S. Naresh, H. Bhowmik, P. Vats, V. Moschos, V. Dzambazova, R. Casotto, S.B. Tiwari, P. Kumar, R.V. Satish, A.K. Srivastava, D.S. Bisht, F. Canonaco, S. Tiwari, D. Ganguly, N. Rastogi, U. Baltensperger, S.N. Tripathi, A.S.H. Prevot, "Long-term Characterization and Source Apportionment of Carbonaceous Aerosols Over Five Sites in Northern India", European Aerosol Conference (EAC) 2019 held at Gothenburg, Sweden, August 25-30, 2019
42. Chinmay, S., A.K. Sudheer, R. Bhushan, "Dynamics of dissolved organic carbon in the northern Indian Ocean", Ocean Science Meeting (OSM 2020), at San Diego, USA, February 16-21, 2020
43. Deepika Sahoo, "C:N:P ratio in the Bay of Bengal during Summer Monsoon", Global Ocean Oxygen Network ($GO_2NE$) Summer School, Xiamen, China, September 2-8, 2019
44. Harsh, R., R. Bhushan, S. Kumar, U. Banerji, C. Shah, "Paleotemperature Reconstruction using Lakshadweep coral", $5^{th}$ Young Earth Scientists Congress (YES 2019), at Freie University, Berlin, Germany, September 9 - 13, 2019
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46. Haslett, S.L., E. Graham, C. Wu, D. Ganguly,N. Rastogi, A. Singh, S.N. Tripathi, U. Baltensperger, D.M. Bell, D. Bhattu, M. Furger, S. Giannoukos, V. Kumar, A.S.H. Prevot, P. Rai, J.G. Slowik, D. Tong, L. Wang, and C. Mohr, "The composition of gas- and particle- phase oxidation products in a high-chlorine environment in New Delhi during the winter", European Aerosol Conference (EAC), held at Gothenburg, Sweden, August 25-30, 2019
47. Kumar, V., S.H. Haslett, A. Bertrand, D. Bhattu, D., D. Tong, D.M. Bell, R. Cassotto, S. Giannoukos, S. Pospisilova, G. Stefenelli, A. Singh, P. Vats, R.V. Satish, U. Baltensperger, D. Ganguly, N. Rastogi, C. Mohr, S.N. Tripathi, A.S.H. Prevot, J.S. Slowik, "Characterization and Source Apportionment of

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50. Rastogi, N., R.V. Satish, S. Tripathi, D. Ganguly, J.D. Slowik, A. Prevot, "Diurnal variability in optical characteristics of water-soluble brown carbon through online measurements over New Delhi", European Aerosol Conference (EAC), held at Gothenburg, Sweden, August 25-30, 2019
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52. Vernier, J-P., H. Liu, V. Ratnam, A. Pandit, D. Fairlie, N. Rastogi, H. Gadhavi, G. Berthet, S. Kumar, and H. Vernier, "The impact of the Summer Asian Monsoon on stratospheric aerosols", European Geosciences Union (EGU) General Assembly 2019, held at Vienna, Austria, April 7-12, 2019
53. Chandana, K. R., "Marine Radiochemistry", University of Puerto Rico, San Juan, Puerto Rico, February 20-22, 2019
54. Niranjan Kumar Kondapalli, D. V. Phanikumar, Manish Naja, Som Sharma, and Tbmj Ouarda, "Impact of Rossby Wave Breaking on the Lower Tropospheric Ozone over Central Himalayan Region", 16th annual meeting of the Asia Oceania Geosciences Society (AOGS), Singapore, 28 July - 02 August, 2019
55. Niranjan Kumar Kondapalli, Som Sharma, D. V. Phanikumar, Shaik Ghousebasha, Manish Naja, Tbmj Ouarda, Venkat Ratnam M., and Karnam Kishore Kumar, "Investigations on Winter Extreme Rainfall Episodes over Central and North Indian Region and the Role of Tropical Extra-tropical Interactions", 16th annual meeting of the Asia Oceania Geosciences Society (AOGS), Singapore, 28 July - 02 August, 2019

**National Conferences**

Oral Presentations: 29

Poster Presentations: 31

1. Arya,R., "Origin of Primordial Black Holes from Warm Inflation", Workshop on High Energy Phenomenology, 1-10 December 2019
2. A. Bhattacharya, J. P. Pabari, S. Jitarwal, K. Acharyya, D. Kumar and S. Nambiar, "Possibility of collision induced cloud charging in Venusian atmosphere", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
3. C. Kumar, S. K. Mishra, P. K. S. Reddy, J. Kumar and K Durga Prasad, "Design and development of a miniature metrology suite for future Planetary balloon missions", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
4. D. Ray, "Geochemical evolution of lunar anorthositic crust as told by meteorite", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
5. J. Jakhariya, J. P. Pabari, S. Nambiar, S. M. K. Praneeth, K. Lad, B. Shah, R. K. Singh, S. Jitarwal, Rashmi, R. Mahajan, K. Acharyya and V. Sheel, "Expected performance of a dust detector in presence of solar wind particles", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
6. J. Kumar, P. K. S. Reddy, S. K. Mishra, C. Kumar, K. Durga Prasad, N. K. Upadhyay, S. A. Haider, V. Sheel and A. Bhardwaj, "Design and Mechanical Analysis of Deployment Mechanism for LPEX experiment onboard MOM-2 Mission", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
7. Jyoti, J. P. Pabari, S. Nambiar and M. R. Reshmi, "Micrometeorite Ablation in Martian Atmosphere", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
8. P. K. S. Reddy, K. Durga Prasad, J. Kumar, V. Sheel, S. A. Haider and A. Bharadwaj, "Development of a Prototype system for PETC", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
9. R. K. Sinha, "Glaciation in the Erebus Montes region of Mars", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
10. R. K. Sinha, "Landing Sites for Mars Surface Science", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
11. R. R. Bharti, I. B. Smith, S. K. Mishra and N. Srivastava, "Study of Subsurface of Lava Province on Mars using SHAllow RADar (SHARAD)", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
12. S. Baliyan and D. Ray, "Microstructural and Microchemical constraints in CM Carbonaceous Chondrite: Implications for Parent Body Processes", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
13. S. Jitarwal, T. K. Upadhyaya, J. P. Pabari, K. Acharyya, V. Sheel, D. Kumar, S. Nambiar, S. Yadav and K. Pandya, "Prototype Design and Testing of Electrically Short Rhombus Antenna for Lightning Detection", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
14. S. K. Mishra and A. Bhardwaj, "Electrostatics on sunlit hemisphere of the Moon", Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020

15. S. K. Mishra, K. Durga Prasad, D. Agarwal, P. Nath and A. Bhardwaj, “Lunar Landing: A Numerical Perspective of its Damaging Effects on Surrounding Systems and Structures”, Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
16. S. Mukherjee, H. Parmar, S. Nambiar, Rashmi, J. P. Pabari, S. Jitarwal, K. Acharyya, V. Sheel and A. Bhardwaj, “Study of dust particle parameter within inner solar system and its role in design consideration for processing electronics”, Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
17. T. Upadhyaya, J. P. Pabari, S. Jitarwal, K. Acharyya, V. Sheel, D. Kumar, S. Nambiar, R. Patel and A. Desai, “Analysis of Antenna Sensitivity at Extremely Low Frequencies for Future Planetary Lightning Experiments”, Indian Planetary Science Conference (IPSC-2020), PRL, Ahmedabad, 19-21 February 2020
18. Pandey, P., Goswami, S. and Shastri, P., “Gender Disparity in Physics in India: Present Status”, Pressing for Progress 2019: An IPA National Conference on Gender Equity in Physics, 19-21 September 2019
19. D. Chakrabarty, D. Pallamraju, Aaditya Sarda, Shashank Urmalia, Rahul Pathak, Pankaj Kushwaha, Mohit Soni, Ayisha Ashruf, Chithra Raghavan, C. Vineeth, Tarun K. Pant, M. Hossain, Dinakar Prasad Vajja, P.P. Pramod, Mohammed Nazeer, Anumod P. G., Ashish Mishra. Arti Sarkar and Ankush Kumar, “NAVA - an experiment designed to detect the hitherto undetected Oxygen airglow emission in Venus from an orbiter”, Indian Planetary Science Conference, PRL, 19 - 21 February 2020
20. N. Srivastava, “INterplanetary Flux Rope Simulator (INFROS) for predicting the magnetic field vectors of ICMEs”, $38^{th}$ meeting of the Astronomical Society of India, IISER, Tirupati, 13-17 February, 2020
21. N. C. Joshi, B. Joshi, and P. K. Mitra, “A complex eruptive circularcumparallel ribbon flare triggered by the Successive stages of flux rope eruption”, $38^{th}$ meeting of the Astronomical Society of India, IISER, Tirupati, 13-17 February, 2020
22. A. Raja Bayanna, “Adaptive Optics system for Multi-Application Solar Telescope at Udaipur Solar Observatory”, $38^{th}$ meeting of the Astronomical Society of India, IISER, Tirupati, 13-17 February, 2020
23. P. K. Mitra and B. Joshi, “Impulsive-eruptive homologous M-class flares originated from a Double-decker flux rope configuration of mini-sigmoid in the $\delta$-sunspot region NOAA 12673”, Young Astronomers meet, Kodaikanal Solar Observatory, Kodaikanal, 23-27 September, 2019
24. P. K. Mitra and B. Joshi, “Multi-wavelength signatures of build-up, activation and eruption of a magnetic flux rope from the solar atmosphere”, National Symposium on Plasma Science & Technology, VIT Chennai, 3-6 December, 2019
25. P. K. Mitra, “Solar Physics: importance, current understanding and yet unanswered problems”, $31^{st}$ Research Methodology Workshop on “Physics and Electronics”, Ahmedabad, India, 18-24 November, 2019
26. H. Kumar and B. Kumar, “Can magnetic-jerk accompanying major solar flares excite seismic emissions in the sunspots?”, $38^{th}$ meeting of the Astronomical Society of India, IISER, Tirupati, 13-17 February, 2020
27. R. Sarkar, N. Srivastava, and A. M. Veronig, “Lorentz force evolution reveals the energy build-up processes during recurrent eruptive solar flares”, $38^{th}$ meeting of the Astronomical Society of India, IISER, Tirupati, 13-17 February, 2020
28. D. Pallamraju, “New directions in upper atmospheric research (Invited Talk)”, PRL Alumni Association: Scientific Workshop on “Research at PRL: Synoptic Perspective”, 24 December 2019
29. D. Pallamraju, “Overview of Space Physics (INVITED Talk)”, ISRO Induction Training Program, 22 November 2019
30. D. Pallamraju, “New results on large scale upper atmospheric variability (KEYNOTE)”, National Conference on Space and Atmospheric Sciences, Sanjay Ghodawat University, Kolhapur, 10 - 11 May 2019
31. Ravindra P. Singh and Duggirala Pallamraju, “Recent results on the MLT dynamics using spectrographic measurements of OH (6-2) and O2 (0-1) band nightglow emissions and corresponding temperatures (INVITED)”, National Conference on Space and Atmospheric Sciences, Sanjay Ghodawat University, Kolhapur, 10 - 11 May 2019
32. Sovan Saha, Duggirala Pallamraju, Subir Mandal, Ravindra P. Singh, and Pradip Suryawanshi, “OI 630.0 nm nightglow emission variability from Gurushikhar, Mt. Abu, a region under the crest of equatorial plasma fountain effect”, National Conference on Space and Atmospheric Sciences, Sanjay Ghodawat University, Kolhapur, 10 - 11 May 2019
33. Duggirala Pallamraju, Ravindra P. Singh, Pradip Suryawanshi, Pankaj Kushwaha, Shashank Urmalia, and Sovan Saha, “Optical experiments for systematic and continuous investigations of mesospheric and thermospheric neutral dynamics”, National Conference on Space and Atmospheric Sciences, Sanjay Ghodawat University, Kolhapur, 10 - 11 May 2019
34. D. Pallamraju, “Road ahead for Atmospheric, Space, and Planetary Sciences in India (INVITED)”, Golden Jubilee Celebrations, Space Physics Laboratory, Trivandrum, 8 - 9 April 2019
35. Ojha, N., Girach, I., and Sahu, L. K., “Tropospheric chemistry over the Indian subcontinent: Space-based observations and modeling”, URSI Regional Conference on Radio Science (URSI-RCRS 2020), IIT (BHU), Varanasi, 12-14 February, 2020
36. Girach, I., Ojha, N., and Nair, P., “Validation of satellite retrieved tropospheric CO and CH4”, URSI Regional Conference on Radio Science (URSI-RCRS 2020), IIT (BHU), Varanasi, 12-14 February, 2020
37. Mallik, C., Ojha, N., and Panda, S. K., “Understanding the distribution of atmospheric sulfur over the Indian region”, URSI Regional Conference on Radio Science (URSI-RCRS 2020), IIT (BHU), Varanasi, 12-14 February, 2020
38. Chutia, L., Ojha, N., Girach, I., Pathak, B., Sahu, L. K., and Bhuyan, P., “Spatio-temporal distribution of sulfur dioxide over South Asia combining observations and model simulations”, URSI Regional Conference on Radio Science (URSI-RCRS 2020), IIT (BHU), Varanasi, (3rd Prize in student paper competition), 12-14 February, 2020

39. Chutia, L., Ojha, N., Girach, I., Sahu, L. K., Sarangi, C., Pathak, B., and Bhuyan, P. K., "Distribution of Trace Gases over South Asia: Model Simulation versus Observations", 4th ISSE National conference (INAC-4), Space Applications Centre, Ahmedabad, 26-27 September, 2019
40. Sourita Saha and Som Sharma, "First observations of Raman Lidar over Ahmedabad", Hindi workshop at PRL, April 2019
41. Sourita Saha, Som Sharma, Niranjan Kondapalli, and Vaidehi Joshi, "Day to day variability of aerosols over a sub-tropical Indian region: A case study", ISSE National Conference (INAC-4) at SAC (ISRO), Ahmedabad, 26-27 September 2019
42. Som Sharma, Niranjan Kumar Kondapalli, Prashant Kumar and Vaidehi Joshi, "Dynamical Coupling of Troposphere-Stratospheric-Mesosphere during Extreme Rainfall Episode over the Indian Low Latitude Region", ISSE National Conference (INAC-4) at SAC (ISRO), Ahmedabad, 26-27 September 2019
43. Kondapalli Niranjan Kumar, Som Sharma, D. V. Phanikumar, and Manish Naja, "Unusual Enhancement in the Tropospheric Ozone in the Central Himalayan Region and its Causative Mechanism", ISSE National Conference (INAC-4) at SAC (ISRO), Ahmedabad, 26-27 September 2019
44. Rahul Kumar Kushwaha, "Residue from VUV Irradiation of Benzene Ices", Indian Planetary Science Conference (IPSC - 2020), PRL, Ahmedabad, 19 21 February, 2019
45. Surendra Vikram Singh, "Fate of Amino Acids and Nucleobases Under Impact Induced Shock -Discovery of Complex Macroscale Structures and Implications to the Origins of Life", 6th National Symposium on Shock Waves (NSSW-2020), IIT Madras, 26 28 February, 2019
46. Swetapuspa Soumyashree, Rituparna Das, R.K. Kushawaha, "Cold Target Recoil Ion Momentum Spectroscopy: Design and Simulation", UltraFast Sciences (UFS 2019),IIT Bombay, November 79, 2019
47. Rituparna Das, Madhusudhan P, Swetapuspa Soumyashree, Pooja Chandravanshi and R. K. Kushawaha, "Strong-field ionization of polyatomic molecules: Ultrafast H atom migration and bond formation in photo dissociation of CH3OH", UltraFast Sciences (UFS 2019),IIT Bombay, November 79, 2019
48. Madhusudhan P, Rituparna Das, Pranav Bhardwaj, Swetapuspa Soumyashree, Pooja Chandravanshi and R.K. Kushawaha, "Study of molecular alignment using femtosecond laser pulses", UltraFast Sciences (UFS 2019),IIT Bombay, November 79, 2019
49. Pranav Bhardwaj, Madhusudhan P, Rituparna Das, Pooja Chandravanshi, Swetapuspa Soumyashree and R.K.Kushawaha, "Design and Development of a new High Harmonic Generation (HHG) setup and XUV beamline", UltraFast Sciences (UFS 2019),IIT Bombay, November 79, 2019
50. Banerji, U.S., R. Bhushan and D. Padmalal, "Hydroclimate variability during the last two millennia and imprints of forcing factors: A study from western India", Sixth Biennial Conference OSICON-19 held at held at CMLRE, Kochi, Kerala, December 12-14, 2019
51. Nisha, B.,, R. Bhushan, M. Muruganantham, "Estimates of paleo deep-water ventilation ages for the Indian Ocean using foraminifera", Climate Change Impacts, Vulnerabilities, and Adaptation: Emphasis on India and Neighbourhood (CCIVA 2019) held at IIT Kharagpur, West Bengal, March, 2019
52. Harsh, R., and R. Bhushan, "Surface ocean radiocarbon variability records from Andaman coral", Climate Change Impacts, Vulnerabilities, and Adaptation: Emphasis on India and Neighbourhood (CCIVA 2019) held at IIT Kharagpur, West Bengal, March, 2019
53. Romi, N., and R. Bhushan, "Paleo-redox condition in the Arabian sea during Last Glacial Maximum and deglacial period", Climate Change Impacts, Vulnerabilities, and Adaptation: Emphasis on India and Neighbourhood (CCIVA 2019) held at IIT Kharagpur, West Bengal, March, 2019
54. Manash Samal, "Jet-bearing YSOs in Vulpecula OB association", The $38^{th}$ Annual Meeting of the Astronomical Society of India (ASI) , IISER Tirupati, 13 - 17 February, 2020
55. Manash Samal, "Properties of an Embedded Cluster in the HII Region Sh2-228: Physical Environment and Star Formation", The $38^{th}$ Annual Meeting of the Astronomical Society of India (ASI) , IISER Tirupati, 13 - 17 February, 2020
56. Manash Samal, "A new-insight to the star-formation in Outer Milky Way", The $38^{th}$ Annual Meeting of the Astronomical Society of India (ASI) , IISER Tirupati, 13 - 17 February, 2020
57. Manash Samal, "Unlocking the star-formation properties of Galactic star-forming regions: A multiwavelength approach", The $38^{th}$ Annual Meeting of the Astronomical Society of India (ASI) , IISER Tirupati, 13 - 17 February, 2020
58. Manash Samal, "Unveiling distance and evolutionary status of six galactic embedded star clusters with GAIA", The $38^{th}$ Annual Meeting of the Astronomical Society of India (ASI) , IISER Tirupati, 13 - 17 February, 2020
59. Manash Samal, "Stellar and substellar mass objects in nearby clusters", The $38^{th}$ Annual Meeting of the Astronomical Society of India (ASI) , IISER Tirupati, 13 - 17 February, 2020
60. Manash Samal, "Unveiling Low Mass Stellar Regime In A Young Proto-Globular Cluster With Subaru Hyper Suprime-Cam", The $38^{th}$ Annual Meeting of the Astronomical Society of India (ASI) , IISER Tirupati, 13 - 17 February, 2020

# Various Events, and Outreach Activities at PRL

**Centenary celebration of Prof. Vikram Sarabhai**

Vikram Sarabhai Innovation Competition (VISION 2019) is a national level competition organized by PRL to commemorate the birth centenary year of Dr. Vikram Sarabhai. The concept of VISION2019 is to promote experimentation in the physical sciences among the science and engineering college students. Project proposals were invited from B.Tech./B.Sc./M.Sc. etc. students which could be executed within 6 months in their colleges. The project grants up to Rs. Three Lacs are to be given to the shortlisted proposals. First, Second and Third prizes of Rs. Three Lacs, Two Lacs and One Lac are also to be given to winner teams, on the successful completion of the projects. The competition opened in February 2019 and total 121 proposals were received in the VISION-2019 program from all over India including several IITs, IISERs, NISERs, NITs, Central and State Universities, government and private engineering colleges etc.


Celebration of Dr. Vikram Sarabhai Centenary.

The proposals were comprehensively reviewed through a three-level screening process that spanned over one and half months and with the help of several PRL and external faculties. 29 PRL faculties from all the research divisions and 9 external reviewers (from IISc, NCRA-TIFR, VSSC-ISRO, National Institute of Hydrology-Roorkee, IITKanpur, IIT-Gandhinagar, Ahmedabad University, NPRL-CSIR) reviewed the proposals as domain experts. Shortlisted proposals were further deliberated by a screening committee with both internal and external faculty members (from IIT Gandhinagar, IPR Gandhinagar, SAC-ISRO) and 11 VISION proposal teams were invited to PRL for their proposal presentation on 30th May 2019. The 11 invited teams were from IIT-BHU, IISERs (Kolkata and Tirupati), NITs (Tiruchirappalli and Durgapur), NISER-Bhubaneshwar, Osmania University, two private universities (Thapar University Patiala and GD Goenka University Gurgaon) and Rajalakshmi Engineering College, Chennai. All or some members of 10 Teams out of 11 have come to PRL for in-person presentations. One team from Osmania University, Hyderabad had presented the proposal via remote presentation option. Total 21 members out of 26 participants have participated in the VISION-2019 in-person presentations and other programs during 29-31 May 2019. A 12 members Selection Committee (with 6 PRL and 6 external members from IIT Gandhinagar, IPR, SAC-ISRO) reviewed all the 11 proposal presentations and recommended 6 teams to be given VISION-2019 project grants. The Selected VISION-2019 Team are from Thapar University Patiala, IIT-BHU, IISER-Kolkata (two teams), IISER-Tirupati, and NIT-Tiruchirappalli. The requested project grants have been disbursed to the selected teams. The teams are currently working on the projects in their colleges/institutions and would be called again to PRL for final round of the competition.

Vikram Sarabhai cOmpetitIon for Concept-Essay Writing (VOICE – 2019) is a pan-India level essay competition organized for the school children. The competition was organized for science popularization among young students, recognition and nurturing of young talent within India. Besides, it can provide a prestigious national platform to showcase their new ideas and imagination. The competition was organized into two categories. Category I for 8-10 standard students, the theme of the essay was “Home at a distant planet.” Category-II for 11-12 standard students, the topic was “Design innovative experiments for space station.” We received about 1000 essays from 24 states and union territories starting from Jammu and Kashmir to Kerala, from Gujarat to Arunachal Pradesh, with more than 50 % participation from the girls. After three rounds of evaluation, 30 students from the category I and 20 students from category II, was invited for presentation at PRL on 11th August, which covered 14 different states. The presentations are judged by a panel of judges from PRL, SAC, IIT Gandhinagar and IPR. A cash prize for 1st, 2nd, and 3rd prize along with five special mention prizes for category I, was awarded. For category II, a cash prize for 1st, 2nd, and 3rd and two special mention prizes was awarded. These students also participated in the inaugural session of Vikram Sarabhai Centenary Celebration on 12 August 2019 organized by ISRO.

**PRL Alumni meet**

As a part of birth centenary year celebration of Dr. Vikram Sarabhai, PRL Alumni Association (PRLAA) organized a scientific workshop Research at PRL: Synoptic Perspective on 24 December 2019 in the K. R. Ramanathan Auditorium, PRL. About 60 Alumni including 12 PhD students (and 33 family members) registered for the workshop. Alumni came from different places like BHU-Varanasi, IITM and IISER, Pune, NIO-Goa, IPR-Gandhinagar etc. There were four invited talks by young alumni and three plenary talks by senior alumni. Dr. Neeraj Rastogi, Secretary, PRLAA convened the welcome session. Prof. P. Janardhan, Dean, PRL welcomed all the participants. First science session was chaired by Prof. Harish Chandra where Dr. Ritesh Mishra gave a talk on super flares from young Sun followed by the review of aerosol chemistry in India by Dr. Kirpa Ram, BHU-Varanasi. Further, Dr. Rajesh Kumar Kushwaha presented some exciting results from Femtosecond Laser Laboratory and Dr. Lokesh Devangan provided a detailed overview of astronomical research being done at PRL. Dr. S. Bhandari chaired the session on plenary talks by senior alumni. Prof. Sunil Kumar Singh, Director, NIO-Goa, discussed about Blue Economy and the role of oceans in facilitating human kind. Prof. M. S. Santhanam discussed the complexity in physical systems: from chaotic dynamics to extreme events. Prof. D. Pallamraju gave a fascinating talk on new directions in upper atmospheric research. There was also a session on reminisces chaired by Dr. R. D. Deshpande in which PRL alumni Drs. J. N. Goswami, M. R. Sivaraman, S. Bhandari, H.S.S. Sinha, and many others shared their memories as a PRL student. Meeting ended with the vote of thanks by Dr. Neeraj Rastogi.

**Celebration of PRL's 72$^{nd}$ Foundation day**

Physical Research Laboratory (PRL), Ahmedabad celebrated its 72$^{nd}$ Foundation Day on 11 November 2019 morning and honoured Dr. Ajay Kumar Sood, Honorary Professor, Indian Institute of Sciences, Bangalore, with Shri Hari Om Ashram Prerit Senior Scientist Award for the year 2018, which was 11$^{th}$ of the series since its inception in 1998. Dr. Sood was given this award in recognition for his outstanding lifetime contributions in the Physics of Nano systems such as graphene and other 2D materials and soft condensed matter, with a strong focus on innovative experiments. The Senior Scientist Award was instituted from funds provided by Pujya Shri Mota of Hari Om Ashram, Nadiad and consists of a Silver Plaque, a Citation and a Cash Prize of Rs. 2,00,000/-.

Along with this, several other awards were presented as follows:

**Shri Hari Om Ashram Prerit Dr. Vikram Sarabhai Research Awards and PRL Awards 2017**

The Vikram Sarabhai Research Awards were instituted from funds provided by Pujya Shri Mota of Hari Om Ashram, Nadiad, and the PRL Award is supported by the Aruna Lal Endowment Fund established by Late Prof. Devendra Lal, former Director of PRL. Each Award carries a Medal, a citation and a Cash Prize of Rs.50,000/-.

The recipients of the Hari Om Ashram Prerit Dr. Vikram Sarabhai Research Awards in different fields were:

1. Space Sciences: Dr. Tirthankar Roy Choudhury, National Centre for Radio Astrophysics, TIFR, Pune, for his outstanding contributions in the field of Theoretical Astrophysics and Cosmology, involving the development of a self-consistent semi-analytical model of re-ionisation, consistent with a variety of observations.

2. Space Applications: Dr. Chintala Sudhakar Reddy, Forestry and Ecology Group, Remote Sensing Applications Area, National Remote Sensing Centre, Hyderabad, for his significant contributions in inventory, monitoring, and assessment of forest ecosystem.

3. Electronics, Informatics, Telematics & Automation: Dr. Manav Bhatnagar, Department of Electrical Engineering IIT Delhi, for his pioneering contribution towards receiver design for multi-antenna systems and fading characterization for next generation communications.

The PRL Award is shared by:

i. Dr. Subimal Ghosh, Department of Civil Engineering, Interdisciplinary Program in Climate Studies, IIT Bombay, for his outstanding contributions to regional hydro-meteorological modeling using statistical and dynamical approaches which has provided new insights into processes associated with moisture transport and land-atmosphere interactions during the Indian summer monsoon; and

ii. Dr. Hetu C. Sheth, Department of Earth Sciences, IIT Bombay, for his outstanding contributions to the geodynamics of the Deccan flood basalts and the tectonomagmatic evolution of the rifted margin of Western India.

Celebration of PRL's $72^{nd}$ Foundation Day

**Buti Foundation Award 2019**

PRL Honoured TWO meritorious Scientists with the Buti Foundation Award 2019 for their significant contributions in Plasma Science and Technology. The Buti Foundation Award was instituted from Buti Foundation, New Delhi. The recipients of the Buti Foundation Awards were:

1. Dr. Pintu Bandyopadhyay of IPR, Gandhinagar, for outstanding contribution in the field of experimental basic plasma physics, particularly in the area of complex (dusty) plasmas.

2. Dr. Dhanya M B of Space Physics Laboratory, VSSC, Trivandrum, for advancing the knowledge of plasma processes in the lunar environment.

This award carries a Medal and a Cash Prize of Rs. 50,000/- and will be presented at a ceremony at the Physical Research Laboratory, Ahmedabad. All the awardees delivered a talk which highlighted scientific contributions made by them.

**Celebration of USO Foundation day**

The Foundation Day 2019 of the Udaipur Solar Observatory was celebrated on 19 September 2019 to commemorate the rich history and growth of the Observatory which was founded in 1975 under the zealous efforts of Prof. Arvind Bhatnagar and his team. This was an occasion to reminisce the tremendous growth and achievements of the facility over the last 44 years. The event was held at USO in the morning with a welcome address by Prof. Nandita Srivastava, Deputy Head USO-PRL, who highlighted the important technical and scientific milestones of the Observatory since its inception.


Celebration of USO Foundation Day 2019, Udaipur.

The special lecture of the day was delivered by the guest of honour, Prof. Dipankar Banerjee, Professor, Indian Institute of Astrophysics Bengaluru on the Long-Term Study of the Sun using Kodaikanal Digitized Data, in which he spoke on the importance of historical observations to understand the processes governing the generation of magnetic fields on the Sun. This was followed by another talk by Prof. Wahab Uddin, Director Incharge, Aryabhatta Research Institute of Observational Sciences (ARIES) Nainital. His talk focused on the Observational facilities at ARIES including the recently commissioned 3.6-m Devasthal Optical Telescope for optical and near-infrared astronomy. The programme concluded with a vote of thanks by Dr. Rohan Louis.

**World Space Week celebrations**

The World Space Week (WSW) is an International event celebrated every year from the 4-10 of October as declared by the United Nations General Assembly in 1999.


Celebration of World Space Week 2019, USO, Udaipur.

This event commemorates the contributions of space science and technology to the betterment of the human condition with a central theme each year. The Moon: Gateway to the Stars has been chosen as the theme for 2019 to honour the 50th anniversary of Apollo 11 and of the first human step on the Moon. On the occasion of WSW, USO organized a one-day outreach event on October 10th 2019 for 50 meritorious students from Classes 9 to 12 and 5 teachers from Govt. Residency Girls Higher Secondary School, Madhuban, Udaipur. USO also provided local transportation for the students and teachers. Dr. Megha Bhatt from the Planetary Sciences Division of PRL Ahmedabad, gave a talk on theme of this year's WSW. An introduction on World Space Week and Space Exploration Events was given by Dr. Rohan Louis. The basic tools for astronomy were explained with a practical demonstration using astro kits which were led by Ms. Sushree Sangeeta Nayak and Ms. Anisha Kulhari. Dr. Girjesh Gupta gave a talk on The Sun and Solar Activity.

**First Indian Planetary Science Conference (IPSC-2020), February 2020**

The Physical Research Laboratory, Ahmedabad, organised the first Indian Planetary Science Conference (IPSC-2020) during 18-20 February, 2020, at PRL, Ahmedabad. The first of its kind in the country, the main objective of the conference was to provide a single platform for the planetary researchers in the country to present and discuss their research accomplishments.

Delegates of IPSC 2020.

IPSC-2020 aimed at highlighting recent results related to the atmosphere, surface and interior of solar system objects and their satellites including various planetary processes and the early solar system. Results from data analysis, theoretical models and observations (ground-based, laboratory-based, remote sensing and spacecraft-based) of various planets and solar system bodies were included in the deliberations under five broad themes. There were two important sessions - an exclusive one-day lunar science meet and a half-day special session discussing the vision and opportunities for future planetary exploration.

There was an overwhelming response with more than 200 abstracts submitted. Nearly 150 contributions were selected for either oral or poster presentations during the conference, which included twenty-four invited talks. Around 200 participants from various universities, academic and research institutions of the country were registered for participating in the conference. These included the young planetary enthusiasts trained in the first Summer Training School on Planetary Science and Exploration organised by PRL in May-June 2019. The conference began with an inaugural session followed by lunar science meet on the first day, which included sessions on science observations from Chandrayaan-2 Orbiter payloads, followed by the present understanding and outstanding questions on lunar science. The next two days included eight oral sessions covering various topics of planetary science - Science and Exploration of Mars and Venus, Solar System processes, Jovian planets, Asteroids and Small bodies, Study of Meteorites and Terrestrial Analogues. As a unique and well-received aspect of IPSC-2020, an opportunity of one-minute oral presentation was provided for all the poster presenters and the posters were evaluated for three categories of wards. The conference was concluded on a satisfactory note with anticipation of wider participation in the next meeting of the series.

**YUVIKA visit**

Thirty-three participants of ISROs special programme YUva Vigyani KAryakaram (YUVIKA) for the school students across the country visited PRL on 14 May 2019. This programme is aimed at imparting basic knowledge to the young students on space technology, space science and space applications in order to arouse their interest in emerging areas of Space activities.

YUVIKA Visit to PRL.

The visit included lectures about PRL as an institute and the diverse set of activities, talks, followed by interaction, on Telescopes, Space and Atmospheric Sciences and Planetary science by PRL faculty members and the Director. Students visited four laboratories in the PRL main campus and four laboratories at the Thaltej campus. There was an active and enthusiastic participation and students were very thrilled, which was clearly evident from their questions during interactions. The visit, coordinated by the Outreach team of PRL, saw an active participation and support of PRL colleagues from academic, scientific and technical as well as administration fraternity.

**Activities on the promotion of Basic Sciences**

**PRL IAPT Dr. VIKRAM SARABHAI Lecture**

The second 'PRL IAPT (Indian Association for Physics Teachers) Dr. VIKRAM SARABHAI LECTURE' was been arranged at on 27 January 2020 at PRL Ahmedabad. The lecture was delivered by Dr. R. D. Deshpande, Chairperson, Geosciences Division, PRL on a topic "Water Resources of India: Challenges and Solutions".


Second PRL IAPT (Indian Association for Physics Teachers) Dr. VIKRAM SARABHAI LECTURE at PRL, Ahmedabad.

The lecture was attended by the participants of structured training programme, students, teachers, IAPT members and PRL fraternity. This lecture will be published in annual Physics magazine Pragaami Tarang, being brought out regularly for the last ten years by the IAPT Regional Council RC-7, Gujarat.

**National Science Day (NSD) 2020 celebrations**

National Science Day (NSD) in India is celebrated on 28 February each year to mark the discovery of the Raman Effect. The primary focus of the NSD celebration is to widely spread the message about the importance of science in the daily life of people. As a result, this event is celebrated all over the country in schools, colleges, universities and other academic, scientific, technical, medical and research institutions. PRL celebrated NSD on 29 February 2020 by conducting various competitive events among the students selected through a screening test held on 5th January 2020. This year three new exam centers viz. 1. Mehsana, 2. Jamnagar, and 3. Amreli was introduced. Five students were awarded the Aruna Lal scholarship selected through personal interview. In NSD-2020, a total of 1188 students appeared in the screening test out of which 1035 and 153 students opted offline and online exam, respectively. The highest marks scored is 107 out of 120. In total, 137 students were selected to participate in various events organized in PRL.


National Science Day Celebrations at PRL

Additionally, to popularize girl child education, PRL invited 104 girl students from schools across Gujarat to visit PRL. Centre toppers of the 18 exam centres were also awarded prizes. In addition, 12 prizes for poster/model competition were given to the students who presented their models/posters on the topics i) My idea of science with Gaganyaan, ii) Learning Science with Fun. This year a maiden activity for teachers was organized, and seven teachers presented innovative teaching models developed by them. In addition, two talks viz. 1. Global Warming and Climate change, and 2. Women in Science: Challenges and way forward were delivered. Screening of a science documentary, "The Climate Challenge", was done, and interaction of participating students and teachers with PRL scientists was the noteworthy activity.

**Science Express**

The second term of the Science Express program started with our presence at the Edufest during 21-22 Dec 2019 to cover the people of the eastern part of Ahmedabad city. For the past three years, about 40 NGOs, in conjunction with more than 100 schools and educational institutions and some industry/corporate partners, have been organizing Edufest event in the Riverfront, Ahmedabad with the primary focus to reaching out general public at large to enthuse scientific spirit, encourage students (and parents alike) to pursue studies, particularly the science stream. The organizers have shown a keen interest in having demonstrations/experiments/posters etc. from PRL and were generous enough to offer exhibition space up to 4000 sq.ft. Here more than 40 Science Express volunteers of PRL, primarily the Ph.D. students, spent their weekend demonstrating 20 odd experiments and interacting with numerous students, kids, and common people. Around 3000 students are expected to be benefited from these two days of activity.

On 4th January 2020, the Science Express team visited Rashtra Katha Shivir, Pransla, Rajkot, Gujarat. Around 25 volunteers visited the Shivir for a day-long activity, setting up several live experiments and interacting with about 1500 participants.

Glimpse of Science Express Phase II

In our third event, the Science Express team visited Vivekaranada College, Dabok and Sangam University, Bhilwara during 10-11 Jan 2020. There were total 40+ volunteers from PRL and USO consists of Ph.D. students, Post-doctorate fellows, scientific staff and few faculty members, demonstrated 20+ live experiments in those two places. More than 1500 and 1600 students participated in these two events, respectively. We also organized a popular science lecture in those two places. It is interesting to note that due to the huge demand from

the students, we had to repeat the public lecture three times in both places.

**NSD celebrations at Udaipur Solar Observatory, Udaipur:**

On 3rd March 2020, a one-day science outreach activity was organized by Udaipur Solar Observatory (USO) at Jawahar Navodaya Vidyalaya (JNV), Mavli, Udaipur, to commemorate National Science Day (NSD), with Women in Science being the theme of the year 2020. The JNV School, Mavli is managed by the Ministry of HRD, Govt. of India, and is located in a rural area about 45 km away from Udaipur city. There were about 540 students (girls and boys) from Class VI to Class XI and 25 teachers of the JNV School who participated in this event.


Glimpses of USO Outreach activities

The programme began with the welcome speech of the Principal of the School and the inaugural address by Dr. Brajesh Kumar. The forenoon session consisted of the following talks by the USO team. Ms. Sushree Sangeeta Nayak spoke on Importance of celebrating NSD and IDWGS & Women In Science. An introduction to The Sun & Research at USO was given by Dr. Rohan Louis. This was followed by a presentation on Solar Activity & Space Weather by Dr. Girjesh Gupta. Ms. Bireddy Ramya highlighted the role of Engineering in Science. Concluding remarks on Career Prospects in Science were given by Dr. Brajesh Kumar.

The talks were followed by an oral presentation competition on the topic “Women in Science” in which 10 students of JNV School from Class IX and Class XI particpated. The best speaker from each Class was awarded a special prize while the rest of the participants were presented a memento. A poster session and demonstration of astro-kits was organized by the USO team in the afternoon, which saw nearly 250 students of Class VIII, Class IX, and Class XI participate with keen interest and enthusiasm. The bilingual posters covered the following topics: Research Activities at USO & Space Weather, Multi-Application Solar Telescope, GONG observing facility, and e-callisto radio observing facility.

The astro-kits comprised simple paper cut-outs of a Sun-dial, star clock, star wheel, clinometer, and solar motion detector. The astro-kit booklets, along with the instructions, were distributed to the students as their home assignment. The event concluded with a vote of thanks by the Principal of the JNV School, Mavli, in which he expressed his gratitude to the USO outreach team and the management of USO/PRL for organizing the event in their School.

**USO Outreach Activities**

**i. Visits to the island observatory and GONG instrument site:**

The Outreach Committee of USO organized several visits of groups of students, from schools, colleges, and universities, in the year 2019-2020. These student groups visited the Multi-Application Solar

Telescope (MAST) located on the island in the Fatehsagar lake and were also shown the Global oscillation Network Group (GONG) instrument and the e-CALLISTO facility in the office premises. The visits were organised on the basis of the requests received from various colleges in India. This year USO organized visits for students from Rabindra Nath Tagore College Kapasan, Pandit Deendayal Petroleum University Gandhinagar, and Vidya Bhawan Polytechnic College, Udaipur. Like previous years, the selected winners of the Astronomy Competition held for school students by the Aryabhat Foundation, Bhopal, were sent to USO on an educational trip on 21st May 2019. A 6 member team of Akashmitra Mandal, an amateur Astronomers' Organization based in Kalyan Mumbai, visited USO and its facilities on 10th June 2019. Participants of the UN-CSSTEAP Space Weather Course also visited the observatory and other solar observing facilities in USO on the 21st of November 2019. In total, the USO team reached out to nearly 150 students/visitors in the year 2019-2020 during their visit to the observatory. Apart from the visits organised at the observatory, the outreach team also stepped out and planned visits at different venues to reach out to a wider student community in and around Udaipur. In this context following efforts made by the USO outreach team are worth mentioning.

**ii. Outreach Activity at Kendriya Vidyalay Eklinggarh, Udaipur:**

Vigyan Prasar and Kendriya Vidyalaya Sangathan jointly organized an Astronomical Telescope Making Workshop at Kendriya Vidyalaya Eklinggarh, Udaipur from 6th to 10th April, 2019. The idea of the workshop was to provide a training platform to selected Kendriya Vidyalaya (KV) students of Classes 10th and 11th for making their own handmade telescope. There were a total of 40 students and 4-5 teachers of KV who participated in the programme. During this event, Dr. Rohan Louis gave a talk titled Introduction to our Sun on 9th April, 2019. The talk covered basic concepts of Solar Physics and the facilities available at USO for carrying out comprehensive investigations of our nearest star.

**iii. Visit of meritorious students of Aryabhat Foundation, Bhopal to USO:**

USO-PRL hosted the annual visit of meritorious students of the Aryabhat foundation on 21 May 2019. A 3-member, school student team visited USO with their mentor. They were first given a short introduction about the Observatory and its existing facilities. Later, they were shown live, high-resolution, small-field images of the Sun from the 0.5m MAST as well as full-disk solar images from the 15 cm SPAR telescope. They also visited the GONG facility and e-Callisto located in the office premises. The enthusiastic student team also gave a short presentation on Life: Earth and beyond. The presentation was followed by a short Q & A session. The Aryabhat Foundation of Madhya Pradesh is focussed on the popularization of Astronomy among the highly motivated, school students of M.P.

**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 the school and college students through hands on experiments, however, with time the chapter has expanded its scientific portfolio by incorporating hands on experiments from other branches of science. So far the PRL student chapter have devised more than 50 hands on basic experiments to explain many phenomena in our daily life. The major activists of the student chapter during 2019-2020 are as follows.

**Students conference**

PRL student chapter organized its annual conference named as Students Conference in Optics and Photonics (SCOP), for the professional development of the PhD students, during 24-26 September 2019.

SCOP 2019

This is a three days conference, organized by the students and participated by the students and post-doctoral fellows from different parts of India. In SCOP-2019, we had 60 students and post-doctoral fellows from 20 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 and abroad working on different fields including optics and photonics, physical chemistry and spectroscopy, planetary science, atmospheric science and biology. Due to this annual conference, the M.Sc., PhD and postdoctoral students from different parts of India get the opportunity to visit PRL with full funding and share their research and build networking among themselves. On the other hand, this conference also enables our PhD students to build leadership quality. In its fourth year, the conference has marked its reputation among the students, researchers and faculties in India and abroad.

**Visiting remote schools**

In continuation of a major outreach program of a different kind which started in 2018 to mark the birth centenary of Dr. Vikram A. Sarabhai, the father of the Indian space program, the Science Express team of PRL has organized the science exhibition/demonstrations at different places of Gujarat and Rajasthan in coordination with schools/community science centers. The motivation of the Science Express event is to reach out to the school and college students with an emphasis on the underprivileged students and also the girl students of rural background and the general public to share the excitement of science. As a result, the student chapter members (majority of the PhD students of PRL are the members of the student chapter) have contributed whole heartedly in the science express events in Gujarat and Rajasthan during December 2019 to February 2020. Demonstration during NSD and open house activity of PRL Like previous years, our student chapter members have demonstrated their hands-on experiments to the students participated in the National Science Day (NSD) activities organized by PRL on 29th Feb 2019.

Different face of the PRL Student Chapter: PRL student chapter is performing its mandate by popularizing science through hands on experiments in different parts of Gujarat and Rajasthan as part of

Science Express of PRL. In addition, PRL student chapter organizes annual conference and get involved in Scientific discussion among their peers.

**Swachhta Pakhwada Celebration 2020**

With an aim to create awareness related to cleanliness, Swachhata Pakhwada was observed in PRL from 01-15 February, 2020. A mass pledge was administered to all staff members to mark the beginning of the pakhwada. Various cleanliness drives were conducted during the pakhwada at all PRL campuses and residential colonies.To encourage a sense of responsibility, the cleanliness drive was followed by drawing and essay competition for the kids. As theatre and drama can be used to effectively teach the society of their present conditions and problems, two schools (KV, SAC and Zydus School for excellence) were invited to present skit on the importance of cleanliness.

To create awareness towards health and hygiene, a medical and hygiene camp was also conducted at Shela village by a team led by PRL doctors, Dr. Samir Dani and Dr. Shital Patel. As a part of this camp, more than 200 hygiene kits were distributed to the participating villagers and the students. Since children are the future of the country, to imbibe the message of cleanliness among them, a lecture cum drawing competition was also organized for middle class students in two municipal schools. The role of the cleaning and house-keeping staff is of paramount importance in maintaining overall cleanliness. Hence, they were sensitized about their contribution to keep the surroundings clean and the health benefits of cleanliness. A lecture was also arranged for them with regard to segregation of waste. Swachhata starts on an individual level, hence, it is very important to make the all staff members aware about it. In this context, two invited talks were arranged during the closing ceremony of Swachhata Pakhwada on 14 February, 2020. The talks were delivered by Shri Paresh Vyas from AMC and Dr. Mona Iyer from CEPT on “Awareness on Solid Waste Management specially emphasizing on the Plastic Wastes” & “Awareness on E- Waste Management” respectively. Finally, following the principle of 3 R’s i.e. reduce, reuse and recycle, various measures have been undertaken to make PRL a plastic free campus.


Glimpses Swachhata Pakhwada 2020 activities

**Vigilance Awareness Week 2019**

The ’Vigilance Awareness Week’ for the year 2019 was observed in Physical Research Laboratory, Ahmedabad from October 28 to November 2, 2019 and the Vigilance Awareness Pledge has been administered to staff members of PRL on 29 October 2019.


Vigilance Awareness Lecture

The banner and various pamphlets with regard to Vigilance Awareness were displayed at prime location of Physical Research Laboratory, Ahmedabad. An awareness lecture on "Integrity-A Way of Life" was arranged on 30 October, 2019 and the lecture was delivered by Mr. Shri K Nityanandam Retired IPS, former DGP, Gandhinagar, Gujarat. An essay writing competition on the topic as a part of vigilance awareness week was also organized on 31 October, 2019 at PRL, Ahmedabad.

**Internal Complaints Committee**

PRL is an institution committed to gender equality, women's rights and empowerment. PRL has a firm zero tolerance stance towards any form of sexual harassment. PRL firmly believes that a sense of security at the workplace will improve women's participation in work, resulting in their economic empowerment and inclusive growth. Since inception in 2010, the PRL Internal Complaints Committee has been meeting at regular intervals to discuss and plan activities as well as strategies to reach and communicate and make sure that the workplace is women friendly.

The Committee has organized several awareness seminars and talks on gender sensitization for PRL employees. The Committee also organizes formal and informal interactive sessions with women employees to understand their concerns. Every year, the committee celebrates International Women's day by inviting prominent thought-leaders to deliver lectures on women empowerment and also distributes souvenirs to its female employees.

Celebrations of International Women's Day 2020 at PRL and Udaipur Solar Observatory

The ICC at PRL makes sure that the policy is communicated to all PRL Women employees and display details of the dedicated officers on all its notice boards. A webpage on Internal Complaints Committee has been also set up on the PRL website. Internal Complaints Committee members are also deputed to attend workshops on prevention of sexual harassment of women at workplace from time to time. During 2019-20 following activities were undertaken:

- On 31 May 2019 and 25 September 2019, ICC members met to discuss and deliberate on ICC brochure and planning the activities for the year ahead.
- On 17 January 2020 an orientation was arranged to sensitize the new entrants men and women both - about the sexual harassment at workplace. The external ICC member Mrs Indu Capoor shared her experience in the field and showed the importance of being alert and aware about sexual harassment in workplace.
- On 8th March 2020, International Womens Day was celebrated with great enthusiasm with entire PRL community comprising of a cultural program, a welcome speech by Prof Anil Bhardwaj, Director, PRL and a very thought provoking talk by Prof Neharika Vohra, IIMA.

In addition, Ms. Pragya Pandey was nominated to attend a workshop on 'Women in Physics' in Hyderabad during 19-21 September 2019. Dr. Shital Patel and Dr. Dilip Angom participated in a workshop on Prevention of sexual harassment at workplace organized by NAHRD at New Delhi during 20-23 January 2020. For the period April 2019 to March 2020, no complaints have been received by the ICC.

### IAS Officers trainee visit to PRL

A Winter Study Tour of Officers Trainees of 2019 Batch of IAS from Lal Bahadur Shastri National Academy of Administration, Mussoorie was organised at PRL in co-ordination with Local Administrative Authorities (Collector Office, Ahmedabad) on 25/01/2020. There were about 18 Candidates and a few representatives of Collector office Ahmedabad visited PRL. The team members after campus walk were given a presentation about PRL and its history and nostalgia by the Director, followed by Lab visit at Space and Atmospheric Science Division and Planetary Science Division. The Registrar PRL and Dean PRL and other PRL members were present in the visit.

IAS Officers trainee visit to PRL

### Celebration of International Yoga Day at PRL

The International Day of Yoga, a Yoga Session in Physical Research Laboratory, was organised at PRL Main Campus, Udaipur Campus and Mount Abu Campus on 21st June, 2019 at 07:00 Hrs. There were about 100 participants in the session and all had participated Yoga enthusiastically. A Trained Yoga Instructor was invited for yoga session. The session was attended by the Registrar, Mr. Chavali V R G Deekshitulu who encouraged and motivated all staff members and Research Scholars to actively participate and practice Yoga on regular basis in our day-to-day life and brightened the event with his presence.

Celebration of International Yoga Day, 21 June 2019

### Celebration of Ambedkar Jayanti at PRL

The $128^{th}$ Birth Anniversary of Dr.Babasaheb Bhimrao Ambedkar was celebrated in Physical Research Laboratory on 14th April, 2019. The programme commenced with lighting of lamp and offering floral tributes to Babasahebs photograph.

Celebration of Dr. Babasaheb Ambedkar Jayanti, 14 April, 2019

Dr. Anil Bhardwaj, Director, PRL recalled the significant contributions of Babasaheb towards shaping up of todays India. He opined that unless life of people in villages and remotest parts of our Country are improved, the real vision of our forefathers may not see reality. The changes in our social set up towards equality and education would be the real tribute to the views of Bharat Ratna Dr.Babasaheb Ambedkar.

Sh. Chavali V R G Deekshitulu, Registrar, PRL and Professor Dr. Angom Dilipkumar Singh, Liasion Officer PRL participated in the event. Beside, a few faculty members and officers of PRL participated enthusiastically.

**Status of Scheduled Caste/ Scheduled Tribe Personnel as on 31/03/2020**

| Centre/ Unit | Total Strength of Employees 2019-20 | Strength of SC Employees | Strength of ST Employees | Strength of OBC Employees |
|---|---|---|---|---|
| PRL | 269 | 12 | 04 | 47 |

**Status of Differently Abled persons as on 31/03/2020**

| 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 | 269 | 5 | 1 | 0 | 0 | 4 |

In addition to the events above, PRL regularly arranges mass pledge activity (in digital and physical modes) on the occasions of Swachhata Pakhwada (during the first fortnight of February), Anti-terrorism Day (May 19), Sadbhavna Diwas (August 18) and, Rashtriya Ekta Divas (October 31). The 'Preamble' of India's Constitution is read on November 26 to mark Constitution day. Celebrations of Independence Day and Republic Day are done in the presence of PRL staff, their family members and CISF personal with great joy and patriotic spirit. To spread awareness about the Fire Safety, a session is organized during Fire Service Week - April 10-15. An awareness talk and demonstration on precautions to be taken during fire events were conducted.

# Capacity Building Programmes

**RESPOND Programme**

Physical Research Laboratory (PRL) administers the Indian Space Research Organization (ISRO) RESPOND programme to provide funding to academia in India for conducting research and development activities related to Space Sciences, i.e. Astronomy and Astrophysics, Astrochemistry, the Physics of Earth's atmosphere/ionosphere, Solar Physics, Space Weather, Space Plasma Physics. The main aim of the RESPOND programme is to encourage quality research in areas of relevance to the Indian space programme.

The RESPOND programme at PRL mainly supports space sciences research in university, college and national institutes for projects of generally 3 years duration. The main deliverables of the RESPOND programme at PRL are PhD theses, research publications in international and national refereed journals and training of manpower. The proposers also get opportunity to request grants for augmenting computational facilities. Occasionally the funding through RESPOND is utilised to set up an experimental facility for research at the university or the host institute. Few projects pursued under RESPOND programme at PRL aim at providing theoretical modeling support to various scientific problems in Space physics, Astrophysics and Earth Sciences. Dr. D. Chakrabarty, Space and Atmospheric Sciences division, Served as a focal point for ISRO-RESPOND project.

During 2019-2020, about 20 project proposals were submitted to PRL for possible funding through RESPOND programme, out of which 14 are at different stages of review and recommendation process, 3 were rejected and 3 were redirected for evaluation at other ISRO centers. One project was approved as ISRO-Space Technology Cell (STC) proposal. The number of previously approved and currently ongoing proposals is 21. These include proposals from different universities and national institutes both.

**Short course on Space Weather**

Space weather plays a very important role in life on Earth and affects almost all aspects of modern society. A clear understanding of space weather has become a necessity for modern civilization. With this view in mind, the Center for Space Science and Technology Education in Asia and Pacific region (CSSTEAP) organized a short course on "Space Weather" conducted at Physical Research Laboratory (PRL), Ahmedabad during 14-27 November, 2019 for the participants from Asia - Pacific region. Twenty seven members from 12 countries took the course. 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 Earth's magnetosphere, ionosphere and thermosphere to Space Weather, Solar influence on middle atmospheric processes, and Effect of Space Weather on electronic and communications systems of Global Oscillation Network Group (GONG) at Udaipur Solar Observatory or USO.


Short course on Space Weather

The participants got exposure regarding the working of the GONG instrument and the data products from GONG The trip to USO ended with a visit to MAST, the Multi-Application Solar Telescope installed on the island in Lake Fatehsagar to observe the photospheric and chromospheric layers of the sun. The working principle and design of the main telescope and the imaging instruments were explained to the students. The adaptive optics system, developed in-house, for compensating atmospheric seeing was also shown and explained. For a better understanding of the theory, there were practical sessions on Measurement of the speed of coronal mass ejection, Measurements of Sunspots (number, area and rotation), Measurement of the geomagnetic field, Radio sounding of the ionosphere, Measurements of TEC and scintillation. Using GPS, and Study of optical signatures of space weather events, they also visited the e-CALLISTO site at USO. Callisto stands for Compound Astronomical Low Frequency Low Cost Instrument for Spectroscopy and Transportable Observatory. The e-CALLISTO system is a valuable new tool for monitoring solar activity and for space weather research. e-CALLISTO is used for the observations of solar radio bursts and radio frequency interference monitoring for astronomical science. At Mt. Abu Observatory, the students learned in detail about the functioning of 1.2 m telescope and the back-end instrumentation. They observed the rings of Saturn through the telescope. As a part of the program, the participants were taken to Udaipur and Mount Abu for a very short scientific tour. The short course ended on $27^{th}$ November with a colorful valediction ceremony. Feedback from the participants was very positive.

**Structured Training Programme**

The ISRO-Structural Training Program (ISRO-STP)-2020 on "Scientific Satellite Missions: payload definition, development and data utilization" was conducted during 22-28 January, 2020. The STP was jointly organized by SAC and PRL and two days program was planned and successfully completed at PRL. The lab visits to three labs; Nano-SIMS laboratory, Optical aeronomy laboratory and VOC laboratory at PRL main campus and four labs at PRL Thaltej campus; SIMPLEX laboratory, Planetary remote sensing laboratory, Payload laboratory and Dust science laboratory was successfully conducted. A scientific visit to the PRL's Mount Abu Observatory had been organized for all STP participants during 25-26 January, 2020. During Mt. Abu Observatory visit the participants were briefed on the observational facilities and significant scientific outcomes obtained using these facilities. A practical session on sky observations through telescope was successfully conducted. Following lectures of one hour each were organized at PRL.

1. Planetary Science Missions: Present and future by Dr. Anil Bhardwaj, PRL

2. Aeronomy missions by Prof. D. Pallam Raju, PRL

3. Planetary atmosphere, ionosphere and exosphere by Prof. Varun Sheel, PRL

4. Planetary remote sensing: Imaging and spectroscopy by Dr. Neeraj Srivastava and Dr. Megha Bhatt, PRL

5. In-situ Planetary investigations: Instruments and Science by Dr. M. Shanmugam and Dr. Amit Basu, PRL

6. Future solar missions by Dr. G. Del Zanna, University of Cambridge, UK

7. Future Astronomy Missions by Dr. P. Sreekumar.

**Induction Training 2020**

Training refers to the learning & development activities carried out for the primary purpose of helping members of an organization acquire and apply the knowledge, skills, abilities, and develop the right attitude, all of which are needed to execute various jobs.


Induction Training 2020

PRL Administration is committed to plan such programme from time to time. In this regard, a Half-Day Orientation Training Programme was organized on 09/01/2020 in Nano SIMS Hall, PRL, Ahmedabad. The Orientation Training Programme was initiated by Shri Rathin Sengupta and Shri Pradeep K Sharma with an intent of making the participants aware about the functioning rules and regulations of PRL/DOS and making them accustomed to the working environment of the Institute. The participants were newly recruited Assistant, Trainee Assistants and Office trainees, deployed in various Divisions/Areas of PRL. The Session began with Introduction of all the members. It covered subjects like Introduction to DOS & PRL, Machinery of the Government by Shri. Pradeep K Sharma, Session on Computer and introduction to COWAA/COINS by Shri. Girish D Padia and Team, Session on Communication Skills and Motivation by Shri Rathin Sengupta, Session on Purchase & Stores by Ms. Nandini R Rao and Mr. Sunil D Hansrajani, Session on Accounts by Shri Suresh Babu and a concluding session on Stress Management by Shri. Anand D Mehta. The Training was well applauded by all and went into interaction mode. It will help the new inductees to not only improve their efficiency and effectiveness at work but also will help in boosting their self-Confidence and assists everyone in self-management.

**Training of PRL Staff**

As a part of the capacity building efforts PRL is sending its staff members (Scientific, Technical and Administrative) for various trainings/workshops from time to time. Following is a summary of PRL staff who attended various training/workshops for the Financial year 2019-2020.

**Scientific and Technical Staff training details**

1. Divyang B Adyalkar, First Aid Training, AMA, Ahmedabad ,27 April, 2019
2. Manisha D Patel, First Aid Training, AMA, Ahmedabad ,27 April, 2019
3. Lokesh Kumar Sahu, STP Course On "New Trends In Remote Sensing & GIS Application", CSTP ISRO, IIRS, Dehradun, 28-31 May, 2019
4. Rajiv Ranjan Bharti, STP Course On "New Trends In Remote Sensing & GIS Application", 28-31 May, 2019
5. Tejas N Sarvaiya, Cyber Security For Digital India, ESCI Campus, Hyderabad, 14-15 June, 2019
6. Padia Girishkumar D, Cyber Security For Digital India, 14-15 June, 2019
7. Shashank Urmalia, Composite Material Technology And Applications, ISIE/ATIRA, Ahmedabad, 15 June, 2019
8. Praggyaya Pandey, 1. Bibliometrics And Research Output Analysis, INFLIBNET, Gandhinagar, 22-27 July, 2019
9. Rishitosh Kumar Sinha, Applications Of Remote Sensing & Geographical Information System, IIRS, ISRO, Dehradun, 26-30 August, 2019
10. Karanam Durga Prasad, Stp On Mission Design Simulation & Operation Challenges, ISRO Gh, Devanhalli, 24-30 August, 2019
11. Praggyaya Pandey, Press For Progress-2019, University Of Hyderabad, 19-21 September, 2019
12. Sourita Saha, $4^{th}$ Isse National Conference-2019, SAC, Ahmedabad, September 26-27, 2019
13. Partha Konar, DTDI Initiated Artificial Intelligence (AI)/ Machine Learning, ISRO HQ, Bangalore, 04-09 November, 2019

14. Akash Ganguly, DTDI Initiated Artificial Intelligence (AI)/ Machine Learning, 04-09 November, 2019
15. Bijaya Kumar Sahoo, Training To Administrative Staff College Of India, Hyderabad , ASCI, Hyderabad, 25 November - 07 December, 2019
16. Srishti Sharma, Internet On Things, ESCI, Hyderabad, 18-22 November, 2019
17. Bireddy Ramya, Internet On Things , ESCI, Hyderabad, 18-22 November, 2019
18. Bhushit G Vaishbav, Intellectual Property Management, RGNIIPM, Nagpur, 25-27 November, 2019
19. Manan Shah, Intellectual Property Management, RGNIIPM, Nagpur, 25-27 November, 2019
20. Veeresh Singh, Very Long Baseline Interferometry Technique For Geodetic Application In India, IIT, Kanpur, 03-04 March, 2020
21. Amit Basu Sarbadhikari, Structured Training Programme, SAC, Ahmedabad, 22-28 January, 2020
22. S Vijayan, Structured Training Programme, SAC, Ahmedabad, 22-28 January, 2020
23. Sanjay Kumar Mishra, Structured Training Programme, SAC, Ahmedabad, 22-28 January, 2020
24. Padia Girishkumar D, $25^{th}$ Innovation Conference On Digital Technologies And Innovations, AMA, Ahmedabad, 18 January, 2020
25. Rahul Sharma, $25^{th}$ Innovation Conference On Digital Technologies And Innovations, AMA, Ahmedabad, 18 January, 2020
26. Sourita Saha, Workshop On Geoportal, Devanahalli Guest House, Bangalore, 18 March, 2020

**Administrative Staff training details**

1. Hitesh Chandulal Panchal, Three Days Workshop On Noting & Drafting, ISTM, New Delhi, 01-03 April, 2019
2. Harsha Parmar, Three Days Workshop On Noting & Drafting, ISTM, New Delhi, 01-03 April, 2019
3. B Anne Matilda, Contracts Management, AMA, Ahmedabad, 24 April, 2019
4. Mantu Meher, Contracts Management, AMA, Ahmedabad, 24 April, 2019
5. Amee Kartik Patel, Goods And Service Tax Provisions, AMA, Ahmedabad, 26 April, 2019
6. Ishita P Shah, Goods And Service Tax Provisions, AMA, Ahmedabad, 26 April, 2019
7. Anshupriya Batra, Goods And Service Tax Provisions, AMA, Ahmedabad, 26 April, 2019
8. Ishita Pravinchandra Shah, Public Procurement, NIFM, Faridabad, 27 May - 01 June, 2019
9. Manisha Mishra, Public Procurement, NIFM, Faridabad, 27 May - 01 June, 2019
10. Nandini Ravi Rao, Public Procurement, NIFM, Faridabad, 08-13 June, 2019
11. Parul Makim, Public Procurement, NIFM, Faridabad, 08-13 June, 2019
12. Suresh Babu A, Procurement (Procedure, Tenders, Bids) & Contracts Management, IICA, Bangalore, 11-14 June, 2019
13. Prabhaben T Chauhan, Effective Office Management, AMA, Ahmedabad, 24 June- 12 July, 2019
14. Vudutala Naresh, Financial Management In Government For DDO/HOO, ISTM, New Delhi, 01-05 July, 2019
15. Dipak J Panchal, Effective Office Management, AMA, Ahmedabad, 24 June- 12 July, 2019
16. Nandini Ravi Rao, GeM And GFR 2017, NIFM, Faridabad, 15-16 July, 2019
17. Pradeep Singh Chauhan, MDP On Export And Import Management, IIFT, New Delhi, 17-19 July, 2019
18. Senthil Babu T J, E-Office, ISTM, New Delhi, 05-06 August, 2019
19. Kuntar Bhagirathkumar K, Noting & Drafting, ISTM, New Delhi, 05-07 August, 2019
20. T S Neethu, Public Procurement, NIFM, Faridabad, 26-31 August, 2019
21. Maniar Razaahmed M, Public Procurement, NIFM, Faridabad, 26-31 August, 2019
22. Mantu Meher, Public Procurement, NIFM, Faridabad, 26-31 August, 2019
23. Debi Prasad Pradhan, Noting & Drafting, ISTM, New Delhi, 02-04 September, 2019
24. Kartik M Patel, Noting & Drafting, ISTM, New Delhi, 02-04 September, 2019
25. K K Sasikumar, Parliamentary Procedures, PARI, Lights, New Delhi, 13-14 September, 2019
26. Suresh H Patel, Workshop On Income Tax, ISTM, New Delhi, 10-11 October, 2019
27. Hitesh C Panchal, Workshop On Income Tax , ISTM, New Delhi, 10-11 October, 2019
28. Dipak J Panchal, Record Management, ISTM, New Delhi, 16-18 December, 2019
29. Ashish G Sawadkar, Traning Programme On RTI, VSSC, Thiruvanthipuram, 19-20 December, 2019
30. Anand Dinesh Mehta, Orientation Training Programme On Drafting In Disciplinary Matters, ISTM, New Delhi, 06-07 January, 2020
31. Chavali V. Deekshitulu, $34^{th}$ Annual Programme For Senior Executives “The Promise Of India-Achieving The Potential To Be Global Leader”, NIAS, Bengaluru, 06-11 January, 2020
32. Suresh Babu A, Workshop On E-Procurement, HRDD, VSSC,Thiruvananthapuram, 21-23 January,2020
33. K K Sasikumar, Workshop On E-Procurement, HRDD, VSSC,Thiruvananthapuram, 21-23 January,2020
34. Nandini Ravi Rao, Workshop On E-Procurement, HRDD, VSSC,Thiruvananthapuram, 21-23 January,2020
35. Rahul Sharma, Workshop On E-Procurement, HRDD, VSSC,Thiruvananthapuram, 21-23 January,2020
36. Priti K Poddar, Noting & Drafting, ISTM, New Delhi, 02-04 February, 2020
37. Keyur Panchasara, Noting & Drafting, ISTM, New Delhi, 02-04 February, 2020

38. Rumkee Dutta, National Conference For DoS/ISRO Women Employees On the Occasion of International Women'S Day, ISTRAC, Bangalore, 20 March, 2020

**Digital initiative in PRL**

PRL, as per the policy of the Department, embarked on digitalization of Office and administrative areas by in-house software and Sandesh in collaboration from URSC Bengaluru.

COINS Finance and Accounts module introduced for MIS purposes from 01.04.2019.

PFMS- EAT module is in operation for making payments as per the Department of Space, Government of India instructions.

Sandesh a dashboard MIS tools developed by the URSC Bengaluru has been successfully implemented in PRL.

A pension portal has been unveiled to have effective communication and facilitate information dissemination to the retired employees. The digital life certificate is also facilitated through this web interface.

The POS machine for receipts, Cash cards for making cash purchase/imprest and to the extent guidelines were implemented.

PRL Council of Management placed its appreciation on record and lauded the PRL's initiatives.

# Official Language promotion at PRL

**Activities on the Promotion of Official Language**

- A Hindi Technical Seminar was organized on 5 April 2019 on the theme "Scientific and Technical Advances in PRL: A vision of Prof. Vikram Sarabhai", in which about 28 scientific papers were presented in Hindi. This year for the first time poster presentations were also held in which around 12 posters were presented. The scientific articles were presented by the respective authors based on scientific and technological activities in PRL. A special invited lecture was also held in the Official Language session. The subject of this talk was 'Parliamentary Committee on Official Language and their observations'.


Dignitaries and participants during Hindi Technical Seminar.

- Being the birth centenary year of Dr. Vikram Sarabhai, the year 2019-20 has a special significance. This year Hindi Pakhwada was dedicated to Dr. Sarabhai commemorating his achievements through various events and competitions. On the day of Inaugural i.e. 14.09.2020, a memoir session of Dr. Vikram Sarabhai was held, in which his colleagues and friends shared their experiences of working with him and his biography was also released on this occasion. During this Memoir session, the present generation at PRL got to know a lot of informative facts about his personality and work. His colleagues and friends made special mention about his humane nature.


Glimpses of various programs of Hindi Pakhwada.

During the Hindi Pakhwada, a *Nibandh* writing competition was held on the topic of "The vision of Dr. Sarabhai" in which about 35 members participated and in the quiz competition related to Dr. Sarabhai about 50 PRL members participated. Also, there was a general popular quiz program Shabd Prashnottari comprised of many interesting rounds in which PRL members participated in groups. A special competition is organized every year for the scientific Areas namely 'Our Work', in which research scholars presents the details of the work being done in their respective areas. Students and teachers of the schools were invited to attend the said program and this way to disseminate the information about ongoing scientific activities of PRL in Hindi. These students and teachers get an opportunity to interact with PRL scientists and best five questions are awarded prizes to encourage the students for interactive participation in such activities. PRL members took part in the Aashubhashan competition and they spoke on given interesting topics based on their eloquence, the winners were decided by panel of judges. In the Vaad Vivaad competition, participants expressed their views on a particular subject 'for' and 'against' the topic. In most of the Pakhwada programs, prizes are given in Hindi and Hinditar categories. Kavita Path competition is a very entertaining event in which the poems and songs self composed by participants are presented and the presentations are really praiseworthy. The best creations were given awards. In the Kavita Path competition, family members also presented their poetic creations.

- Hindi Patrika Vikram Birth Centenary Special Edition dedicated to Dr. Vikram Sarabhai was released on 11.11.2019 in which many former senior PRL scientists and members of Sarabhai family were present. It was a moment of great pride and honour.

Hindi Patrika Vikram Birth Centenary Special Edition release.

- A Hindi workshop is organized in every quarter on various topics regarding usage of Hindi. In Hindi workshops, members of different Sections are nominated by turn according to their work profile. A special workshop was also organized for scientific book writing in Hindi to provide guidance about original book writing in Hindi.
- On 19 November 2019, Controller, SCL visited PRL for Departmental Inspection regarding progressive use of Official Language.
- Space Applications Centre, Ahmedabad organized Hindi Memory Competition on 26.11.2019 at Town Official Language Implementation level, in which two members of PRL - Mrs. Sneha Nair - Consolation Prize (Language region- C ) and Ms. Amarjass Sekhon - First Prize (Language region- B) won prizes.

Presentation of memento to Shri Kamlendra Sarbhai, Deputy Director General Doordarshan speaker by Prof. Anil Bhardwaj, Director, PRL.

- A talk on “The Role of Doordarshan in promotion of Hindi” was organized wherein Shri Kamlendra Sarbhai, Deputy Director General Doordarshan delivered a presentation on the subject.
- As per the Official Language Rules, PRL regularly conducts meeting of the Official Language Implementation Committee, which is chaired by the Director. In all these meetings, policy decisions related to implementation of Hindi are taken and the progressive use of Hindi in the entire office is discussed.
- Every year various competitions are organized by the Town Official Language Implementation Committee for promotion of the Hindi language. In the series, a Hindi Essay Competition was organized by Physical Research Laboratory, Ahmedabad on 18.06.2019 on behalf of Town Official Language Implementation Committee level whose title was - “Multi-specialty hospital - treatment or business”. 51 entries were received from various Central Government offices in Ahmedabad. The names of the prize winners of the Hindi essay competition are as follows:

    1. Shri Dharmendra Passi, Central Warehousing Corporation, First Prize
    2. Ms. Alka, Physical Research Laboratory, Second Prize
    3. Shri Karthik Patadia, Central Warehousing Corporation, Third Prize
    4. Shri Vaibhav Dixit, Physical Research Laboratory, Consolation Prize
    5. Shri Apoorva Prajapati, Space Applications Center, Consolation Prize

# Facilities and Services

**Computational Services Group**

The Computational Services Group (CSG) 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, software development and maintenance.

Apart from this, Computational Services Group members have been actively participating in various ISRO/DOS level Cyber Security Vulnerability Assessment & Penetration Testing (VAPT) activities.

Following services/facilities are added/upgraded/provided during the year 2019-2020.

**[A] Web Site/Web Application:**

1. **Paperless Assets Tracking System eSampatti software**:

   Physical Asset verification is the essential part of any organization and it is conducted in PRL on yearly basis. The asset verification is in PRL includes visit of a team member to each indenter and verification of the assets available with him/her. The verification details are recorded in a physical sheet which later on reconciled by the Store department. The entire process is manual and time consuming. To overcome this issue, Computer Centre has developed an application ”eSampatti” (compatible with desktop and mobile phone platforms). eSampatti has in-built barcode scanner which scans barcoded items, fetches those details from central database (i.e. CoWAA/CoINS) and displays the information about the item, hence he item can be tagged appropriately in eSampatti. eSampatti, while keeping the track of each item verified and providing various reports like; Custodian wise Asset details, Division Wise Asset Details, Verification Status, etc. Once the verification is complete, custodian wise asset report can be printed through eSampatti and signed by custodian.

2. **Newly Developed Website for Pensioners - Retired Employees Portal**:

   Computer Centre has designed a new bilingual website for Retired Employees. The website has been developed using Angular 6 as frontend and PHP as Backend. The communication between client and server is being done using REST APIs. This technology makes our client and server code independent of each other and can be deployed on different servers. Following are the new features of website:

   - The website has Responsive Design i.e. easy to navigate on devices like smartphones.
   - All the registered pensioners can register on website and they can get their pension slip, income tax estimation etc.
   - All the pensioners can contact Administration, Accounts and medical section by submitting their queries online.
   - All the pensioners can get Office Orders/Notices related pensioners.
   - Contact details of Medical Officers, PRL Employees and Retired Employees.
   - Downloads of various forms like Life Certificate, Medical Certificate, Medical Reimbursement form.

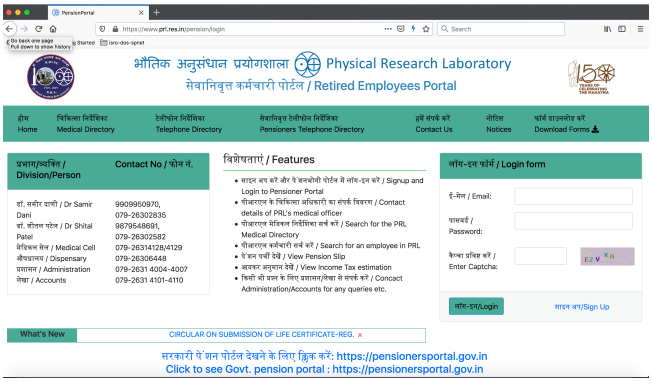


Figure 1: Pension Portal

3. **VIkram Sarabhai Innovation CompetitiON (VISION) - 2019 Website**:

   To celebrate the birth centenary year of Dr Vikram A. Sarabhai, the father of the Indian space programme, Physical Research Laboratory organized a Pan India level competition to support the new and original ideas, which has potential for new innovations for the students pursuing their B.Sc., Integrated M.Sc., M.Sc., B.E./B.Tech. and preferably in pre-final year.

   To disseminate the information about this event a Website/Web application was developed. Using this Website/Web application students get information related to : VISION competition.

4. **Pan-India Essay competition - VOICE Website** :

   To celebrate the birth centenary year of Dr Vikram A. Sarabhai, the father of the Indian space programme, Physical Research Laboratory organized a Pan India level essay competition for student of Standard 8-10 and Standard 11-12. To disseminate the information about this event a Website/Web application was developed. Using this Website/Web application students who want to participate in VOICE 2019 competition, were able to submit their essay conveniently.

5. **Online Examination Software for National Science Day** :

   Software has been developed to conduct online examination over Internet for National Science Day organized by PRL. Total 153 students from 25 school appeared for online examination mode on 05/January/2020. To provide support during online examination, Two Help Line numbers for the schools has been provided.

6. **Software for Hindi Section for Hindi work consolidation requirement** :

   Software has been developed for Hindi Section and Divisions to upload their Hindi related work inputs through online portal. The software provides consolidated report in the format required by Rajbhasha Vibhag, Government of India.

7. **Online Quiz Competition Software Hindi Pakhwada** :

   Software has been developed to conduct competitions like Daily Quiz, Hindi Gyan, and Hindi Typing online over PRL Intranet during Hindi Pakhwada.

**[B] Data Networks and Services:**

1. **Application Virtualization (AV) Infrastructure setup** :

   Application Virtualization (AV) is a Virtual Desktop Infrastructure (VDI) based implementation in PRL. In VDI, the desktop based operating systems are installed on managed at central servers. The desktop image on application is presented to the end user and it interacts with user in such a way that it is running locally on user's device. The endpoint devices can be either Windows/Linux/Apple Mac OS or even a mobile device.

   Following are the major advantages:

   (a) Platform Independent access of applications like MS Office, Sigma Plot, Internet Explorer on Linux, MAC

   (b) Easy Maintenance/Upgradation of OS and Applications.

   (c) PRL User can store their data in local PC/Laptop drive OR even on central servers with disk quota of 30GB.

   (d) It supports Local Printer to print the documents.

   (e) The AV setup is accessible over Internet through secure channel Virtual Private Network (VPN).

   (f) Antivirus software is installed for virus protection.

2. **Chandrayaan-2 XSM and APXS Payload Server hardening & Secure Connectivity with ISSDC, ISRO** :

   CSG has provided dedicated public IP based access between XSM and APXS payload data server and ISROs ISSDC servers from Thaltej campus Internet Gateway by following all security guidelines of PRL IT security policy. CSG has taken appropriate measures for essential Server Security hardening tasks on Chandrayaan-2 XSM and APXS payload data server in close co-ordination with custodian of the server.

3. **Upgradation of Wifi Devices** :

   To improve the wireless network connectivity and enhance PRL user's WLAN experience the existing WiFi access points deployed at important locations of PRL Main Campus and Thaltej Campus has been replaced with new dual band Ruckus AP R720, which supports IEEE Wi-Fi Standards 802/11 a/b/g/n/ac Wave 2, and its Peak PHY Performance Rates for 2.4GHz is 600 Mbps and for 5GHz is 1733 Mbps which is much improved as compare to existing APs. Following are the key points of activity performed:

   (a) Total existing 28 ZF7372 Wifi devices has been updated to Ruckus R720 (12 in PRL Navrangpura Campus Multistory building and 16 in Thaltej Campus include area such as Student hostel, Main building and New Building).

   (b) Extended coverage with patented BeamFlex+ utilizing multi-directional antenna patterns

   (c) Improve throughput with ChannelFly which dynamically find less congested Wi-Fi channels to use.

4. **Network Devices Upgradation** :

   As per DOS/ISRO and PRL IT security Guidelines and Industry standard best practices we also carryout firmware up-gradation of all the Network Switches, WiFi Access Points and Controllers immediately when an update comes.

5. **Centralized Log-Server for log co-relation** :

   Recently we had established PRL's Centralized Log Server to store/archive logs from multiple critical servers/IT-services of PRL using open-source tools and technologies. As the logs are archived at central location it will be useful during log correlation activity at the time of any cyber security incidents for PRL's IT services like proxy, mail, DHCP, VPN, webserver etc. This is in compliance with action item suggested to all ISRO/DOS centres/units under IIIP program as per ISRO/DOS IT security policy.

6. **ISRO/DOS Network SPACENET** :

   SPACENET is a Close User Group (CUG) network of DOS/ISRO Centers/Units. This network is used for accessing Intranet of other DOS/ISRO Centers/Units. To strengthen the security of SPACENET network, IPTABLES based firewall and SQUID proxy server has been already working at gateway level to secure the SPACENET Network. To further strengthen the security at gateway level in compliance with DOS/ISRO/Govt. of India Norms/Policy, squid authentication over SSL which uses LDAP over SSL has been implemented for PRL SPACENET network.

7. **Software Upgrades** :

   Computational Services Group has updated software like Matlab, IDL and Eset Anitvirus.

8. **Closed Circuit Video Surveillance(CCTV) Setup for Creche**:

   Computational Services Group has setup a Closed Circuit Video Surveillance System at newly setup Creche near Guest House.

**[C] Vikram 100 High Performance Computing Cluster:**

Vikram100 - 100TF High Performance Computing (HPC) facility is extensively used by PRL Scientific & Technical fraternity. During April 01, 2019 to March 31, 2020 period 10 Scientific Papers have been published in reputed Scientific Journals where Vikram100 facility is acknowledged. In total, 61 Scientific Papers have been published since June 2015.

## Library and Information Science

Library and Information Services plays an important role in catering to the information needs of the PRL researchers and staffs. These information services are being provided in all the campuses of PRL. The name 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. Library also provides the Inter library loan facility, Plagiarism Check facility through Ithenticate tool, Reprographic facility, Information display through Digital Notice Board and book procurement. The updates and additions to the library during the year 2019-2020 are mentioned below:

### Statistics

In the year 2019-20, there has been an addition of 242 Scientific, 61 General and 93 Hindi books and 13 CDs/DVDs to the collections of three libraries in Main, Thaltej and USO campuses. 4247 visitors visited the library during the year. The Library provides Inter Library Loan (ILL) service for its users and to other Institutes as well 89 ILL requests, were fulfilled by PRL and 24 articles were sought from other institutes. Library facilitates research scholars for buying books based on their requests. Through its important reprographic service to support research, library provides photocopies of material requested by researchers. 346 e-books and 194 journals are accessible to the Library users.

### Library Online Resources

PRL Library continues to have access to full-text databases like AGU Digital Library, GSA Archive, PROLA, Science Archive, Proquest Dissertation and Theses (PQDT). In 2019, Library got the access to complete Nature and Springer ebooks, in Engineering with addition to SPIE and IEEE Digital Library through Antakriksh Gyaan which is an ISRO Library Consortium. From Jan 2020 all the ISRO libraries are able to access 603 Springer e-journals. The Library homepage gives access to this digital content. The PRL library also subscribes to Discovery Tool which searches a topic through all the journals simultaneously with filters like full-text and peer reviewed.

### Plagiarism Check Facility

Library is responsible for carrying out the similarity check for students using the Ithenticate tool. They avail this facility before submitting the thesis; users also get their content checked for originality for the research papers they submit to various journals.

### Digital Notice Board

It is maintained by the library to disseminate information about PRL activities like division seminars, colloquia, public talks, images of events like Republic Day celebration, Womens Day celebration, etc. In addition, list of recent publications of PRL scientists, new books added to the library collection are also displayed in Three campuses simultaneously through the LAN. Mt. Abu campus will be linked soon.

### Institutional Repository

The Institutional repository maintained by the Library consists of journal articles published by the PRL authors from 1990 to present and is also linked through the Library homepage. About 4300 articles by PRL authors are now part of this repository. All the PRL theses from 1952 onward (430) are now available full text for PRL users. All the Technical Notes since 1977, published by PRL have been digitized (114) and are available full text for PRL users. Currently, Library is carrying out the digitization of the photographs archive. Scanning of the photographs of 250 albums is completed. Giving the captions and metadata for each photograph for easy retrieval is in process using the digital library software - Greenstone Digital Library (GSDL).

### Library Outreach

PRL Library hosted the annual ADINET seminar on 14 September 2019 as part of Vikram Sarabhai centenary celebration. More than 200 delegates attended the seminar from all over Gujarat and a few delegates from other ISRO centres like VSSC and LPSC.


Figure No. 1: Group Photograph of ADINET Seminar.

Figure No. 2: Release of ADINET Directory by the dignitaries.

## Workshop

PRL's mechanical workshop has been providing support to the research and development (R&D) activities of all the academic divisions of PRL. The workshop has its facilities in Navrangpura and Thaltej campuses. It is equipped with the state-of-the-art machines for the manufacturing of mechanical parts, e.g., Vertical Machining Centre (VMC 640), Wire-cut electrical discharge machine (EDM), CNC turning centre (DX 200), etc. The workshop also uses several CAD software (e.g., AUTOCAD, SOLIDWORKS, etc.) to assist with various aspects of designs. In the academic year 2019-2020, the workshop played a significant role in the development of the femtosecond laser laboratory, ASPEX payload on upcoming ADITYA-L1 mission, the laboratory model development of several proposed experiments, development of several systems for research applications and to support the routine requirements of several R&D laboratories in PRL. The workshop has also been providing support for the maintenance and repair activities of various set-ups and equipment in PRL. Some of the major projects undertaken by the workshop in this year are discussed below:

### 1. Activities related to the development of Femtosecond Laser Laboratory

The newly established femtosecond laser laboratory in PRL main campus is one of the kind in the country. This laboratory poses stringent and precise requirements, which include anti-vibration floor isolation, cleanroom, and temperature and humidity-controlled environment for optimal functioning of the highly sensitive equipment placed in this laboratory. The workshop has actively participated in the development of its various components and assemblies. In particular, a 'Cold Target Recoil Ion Momentum Spectrometer' has been developed for coincidence momentum imaging, to be used with the femtosecond laser for carrying out the ultrafast science. The assembly of the spectrometer is shown in figure-1, panel (a.). PRL workshop has manufactured various components of the system, e.g. drift tubes, aluminium mesh holders, ceramic spacers, stainless steel (SS) and aluminium flanges, etc. Each of these parts was produced in varying quantities and have dimensions from as small as 2 mm to as large as 140 mm.


Figure No. 1 : Panel (a.) shows the mechanical assembly of the Cold Target Recoil Ion Momentum Spectrometer. Various mechanical components of the system were manufactured within the workshop. Panel (b.) shows a part of the Velocity Map Imaging Spectrometer.

The laboratory also operates a 'Velocity Map Imaging Spectrometer' to measure the velocities of ions and electrons which originate from the interaction of atomic and molecular systems under study with the intense femtosecond laser pulses. The workshop had produced the critical support structure for this instrument to ensure the stability requirements of the instrument. These include the support structures for its CCD camera (as shown in figure-1, panel (b.)), vacuum chambers, piezo pulse valves for the CCD camera, etc. A very special skimmer mount was designed and fabricated as per requirements of the velocity map imaging spectrometer. The skimmer mount is very critical for alignment of the molecular beam, as it has to pass through the narrow opening ($\sim$200 microns in diameter) of the skimmer. The size of the skimmer itself is only 1.01 mm. The fabrication of skimmer mount required a high precision in machining and orientation. Figure-2 shows the dimensions and drawings of the skimmer mount.

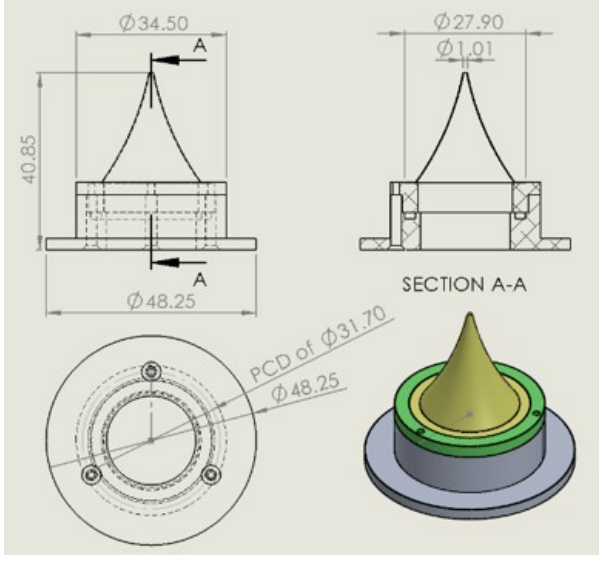


Figure No. 2 : The design of the Skimmer mount for the Velocity Map Imaging Spectrometer.

Figure No. 3 : A set-up of the femtosecond laser laboratory.

The workshop had also developed the other required accessories like protective enclosures for the femtosecond laser, instrument racks,

mounting the vacuum chambers, etc. During the entire endeavour, the workshop had provided its support from developing the CAD models to the installations of the laboratory set-up as shown in figure-3.

## 2. Activities related to Space Instrumentation and Payload Development

The workshop is actively involved in the development activities of several planned and proposed instruments for various space missions. Various components, for the experimental prototypes, for the test settings and the flight models of these payloads have been manufactured. Aditya Solar wind Particle Experiment (ASPEX) is a payload on ISROs upcoming ADITYA-L1 mission. The mechanical components for the flight model of ASPEX as well as the parts required for its testing/calibrations had been fabricated in the workshop. A test set-up for the screening of multichannel plate (MCP) detectors (to be used in the payload), has been designed and manufactured. The set-up includes a mounting assembly, an aluminium mask, stainless steel anode, etc., along with multiple Delrin spacers for electrical isolation. Four such assemblies were developed to be used simultaneously for such screening tests. Figure-4 shows some of the components of the MCP detector of ASPEX and the test set-up, as developed in the workshop.

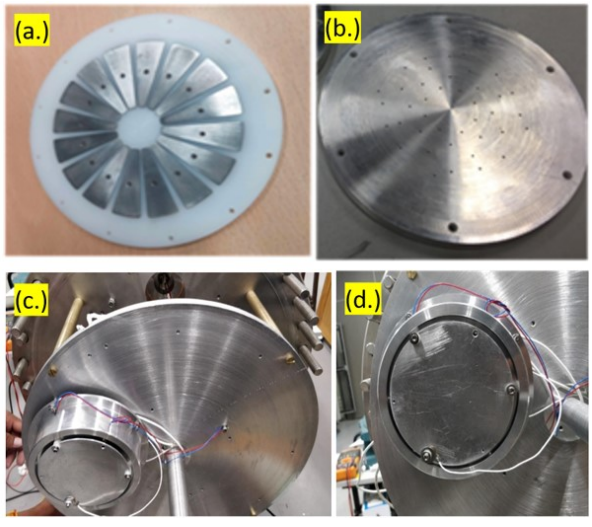


Figure No. 4 : Various components and test assemblies developed for ASPEX payload. Panel (a.) shows continuous anode for MCP calibration; Panel (b.) shows MCP mask having 0.7 mm diameter holes developed for the testing of Resistive Anode Encoder; Panels (c.) and (d.) show the mounting assembly for MCP detector screening and qualification tests.

The prototypes and laboratory models of several other proposed instruments had also been developed in the workshop. The mechanical sub-systems of the laboratory prototypes for a dust detector, CUBE SSD Based X-Ray spectrometer, Langmuir Probe and Electrical Field Experiment (LPEX), etc., have also been developed in the workshop.

## 3. Other Developmental Activities for Various Divisions of PRL

The workshop is actively engaged in the development of multiple instruments and set-up for various PRL research laboratories. The Near-Infrared Spectrometer and Polarimeter (NISP) for the upcoming 2.5 m telescope at Mt. Abu is cryogenic cooled instrument and is under development. The workshop has made significant contributions for its several vacuum compatible mechanical components, e.g., aluminium test chamber, copper plate adaptor, aluminium cold-plate, FR4 supports, titanium brackets, detector mount, thermal shield, etc. Figure-5 shows some of these components that were manufactured in the workshop.

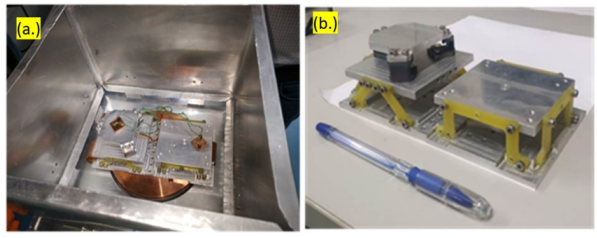


Figure No. 5 : (a.) NISP detector-mount with radiation shield in the chamber (b.) NISP detector mount.

PRL Radial Velocity Abu Sky Search-2 (PARAS-2) spectrograph is another instrument currently under development. The spectrograph requires a highly stable support structure for the optical bench to test its precision optical components. These mild steel support structures have been developed in the workshop. These structures have been designed to take a load of 600 to 700 kg. The support structures are to be used with granite slab, and steel bread-board to provide a platform for PARAS-2 optics testing.

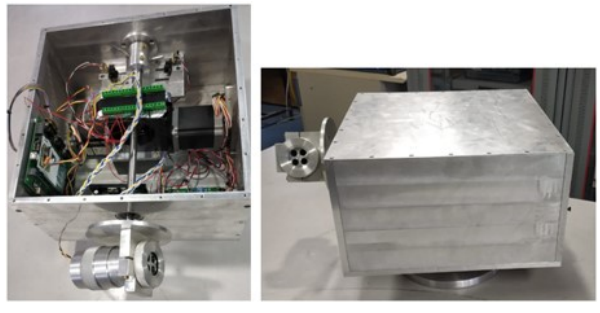

Figure No. 6 : Dual-Axis Hybrid Sun Tracking System.

The development of adaptive optics system required a turbulence generator to simulate the atmospheric turbulence. It is based on mixing of ambient air, and temperature-controlled hot air at regulated air flows within a restricted chamber. One such hot air-based Optical Turbulence Generator (OTG) has been designed & fabricated in-house in the workshop. This OTG is equipped with a heater, two fans and several sensors to generate the air-flow of desired characteristics. The set-up is currently being used to simulate the required properties of turbulence in the laboratory.

A variety of instruments for tracking the movement of sun for atmospheric aerosol studies and day time airglow observations have been designed and developed by colleagues of PRL with the support of the workshop. They include dual-axis hybrid Sun tracking system, sky imager system, CCD Based Multi-Wavelength Airglow Photometer (CMAP), etc. CMAP has been installed at the Optical Aeronomy Observatory in PRL's Thaltej campus in 2019.. The dual-axis hybrid Sun tracking system (figure-6) requires real-time tracking of the Sun, thus posing a demand for precise motion control mechanism. This has

been developed with two drive motors with worm gear mechanism for accurate elevation and azimuth tracking using a feedback mechanism. The controller and driver electronics are also mounted inside the system.

The workshop has also modified and manufactured an existing aerosol sampling system which is used to quantify the effect of relative humidity (RH) on various atmospheric aerosol properties. The system has been significantly modified to an automatic regenerating adsorption dryer for continuous operation. It consists of two sets of the aluminium cylinders (length 6 feet and diameter 6 inches), houses 11 ducts (diameter 10 mm) of stainless-steel wire mesh, inlet and outlet cones, and is filled with silica beads.

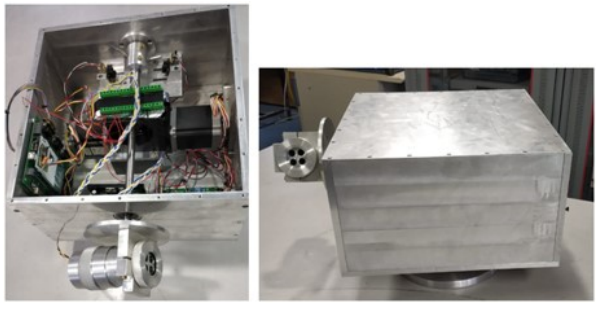

Figure No. 7 : Aerosol Sampling System.

The cones are mounted with temperature and RH sensors to monitor the change in the relative humidity. During the real-time operation, when the ambient air is sampled through a cylinder, the other cylinder is being dried automatically. The system (as shown in figure-7) has been installed at Aerosol Monitoring Laboratory by the workshop team.

The workshop has also designed and built various other systems, e.g. (a.) an isolation cage system to provide isolation for a high voltage experiment. The cage is grounded from all sides and has a floating platform which can be biased up to 20kV; (b.) a compact low-cost heater assembly for the graphite preparation in radiocarbon dating laboratory; (c.) a glove box (with the isolated chamber and input-output valves) for organic chemistry laboratory to be used for the chemical treatment of meteorite samples, etc.

**4. Other Support Activities**

The PRL workshop has also been engaged in several support activities for the routine functioning of various R & D laboratories of PRL. Some of them are mentioned below:

a.) Manufacturing of stainless-steel holders and a storage container for hard X-ray optics foils.

b.) Installation of linear guides for a vacuum chamber closure mechanism for planetary environment simulation.

c.) Manufacturing of Graphite pressing units for the Atomic Mass Spectrometer (AMS) laboratory.

d.) Mechanical enclosure development of a motion control system for MFOSC-P instrument, support structure and stand for a CCD camera, Teflon Housing for Filter Wheel, enclosure box for electronics etc.

e.) Repairing a vacuum pump for Nano-SIMS laboratory, etc.

# Honorary Fellows & Faculty

**Honorary Fellows**

A. Hewish

J. E. Blamont [Deceased 13 April 2020]

K. Kasturirangan

P. J. Crutzen

**Honorary Faculty**

A. K. Singhvi
FNA, FASc, FNASc, FTWAS
DST-SERB-Year of Science Chair Professor

J. N. Goswami
FNA, FASc, FNASc, FTWAS
INSA Senior Scientist

S. A. Haider
FNA, FASc, FNASc & J. C. Bose Fellow

M. M. Sarin
FNA, FASc, FNASc
DST-SERB-Distinguished Fellowship

Shyam Lal
FNA, FASc, FNASc
CSIR Emeritus Scientist

S.D. Rindani
FNA, FASc, FNASc & J.C.Bose Fellow

D P K Banerjee
CSIR Emeritus Scientist

# PRL Faculty

| Sr. No. | Name | Designation | Specialization | Academic Qualification | Division |
|---|---|---|---|---|---|
| 1 | Bhardwaj A. (FNA, FASc, FNASc) | Director | Planetary & Space Science | Ph.D. (1992) | ADMDIR |
| 2 | Acharyya K. | Reader | Astrochemistry | Ph.D. (2008) | PSDN |
| 3 | Adalja H. L. | Scientist/Engineer-SD | Mechanical Engineering | M.Tech. (2009) | A&A |
| 4 | Adhyaru P. R. | Engineer-SF | Development of Electronic Sub Systems For Spectrometry | B.E. (1991) | GSDN |
| 5 | Agrawal R. L. | Scientist/Engineer-SD | Mechanical Engineering | B.Tech. (2013) | CMDV |
| 6 | Banerjee D. | Professor | Thermoluminescence and Planetary Physics | Ph.D. (1997) | PSDN |
| 7 | Banerjee S. B. | Scientist-SF (Ret. 31.07.2019) | Experimental Molecular Physics | Ph.D. (2012) | AMOPH |
| 8 | Basu Sarbadhikari A. | Asso. Professor | Planetary Geochemistry | Ph.D. (2007) | PSDN |
| 9 | Bayanna A. R. | Scientist/Engineer-SE | Optical Instrumentation & Solar Physics | Ph.D. (2015) | USO |
| 10 | Bharti R. R. | Scientist/Engineer-SD | Computer Science | M.Sc. (2003) | PSDN |
| 11 | Bhatt J. R. | Professor | Astrophysics | Ph.D. (1992) | THEPH |
| 12 | Bhatt M. U. | Scientist-SD | Planetary Remote Sensing | Ph.D. (2012) | PSDN |
| 13 | Bhattacharyya R. | Asso. Professor | Plasma Physics | Ph.D. (2006) | USO |
| 14 | Bhavsar K. J. | Engineer-SE | Electrical Systems | B.E. (1995) | CMDV |
| 15 | Bhushan R. | Scientist-SG | Oceanography and Paleoclimatology | Ph.D. (2009) | GSDN |
| 16 | Bireddy R. | Scientist/Engineer-SD | Embedd Systems | M.Tech. (2019) | USO |
| 17 | Chakrabarty A. | Professor & Chair, A&A | Extra-Solar Planets, Star Formation & Instrumentation | Ph.D. (1999) | A&A |
| 18 | Chakraborty D. | Asso. Professor | Space Weather | Ph.D. (2008) | SPASC |
| 19 | Chauhan N. | Reader | Luminescence Dating and Luminescence Dosimetry | Ph.D. (2012) | AMOPH |
| 20 | Dani S. V. | Medical Officer-SF | Medicine | MBBS (1993) | DISSR |
| 21 | Deshpande R. D. | Scientist-SG & Chair, GSDN | Application of Environmental | Ph.D. (2007) | GSDN |
| 22 | Dewangan L. K. | Reader | Astrophysics | Ph.D. (2011) | A&A |
| 23 | Dixit V. | Scientist/Engineer-SD | Scientific Computing | M.Tech. (2017) | A&A |
| 24 | Doshi S. H. | Technical Officer-D | Electronics | Dip. In Electronics & Radio Eng (1982) | A&A |
| 25 | Durga Prasad Karanam | Reader | Planetary Surface Science & Instrumentation | Ph.D. (2018) | PSDN |
| 26 | Gadhavi H. S. | Asso. Professor | Atmospheric Physics | Ph.D. (2006) | SPASC |
| 27 | Ganesh S. | Scientist-SF | Milky Way, Comets, Agn, Astronomical Polarimetry | Ph.D. (2010) | A&A |
| 28 | Goswami S. (FNA, FASc, FNASc) | Senior Professor | High Energy Physics | Ph.D. (1998) | THEPH |
| 29 | Goswami V. | Reader | Spatial and Temporal Variations of Isotopes and Redox Sensitive Elements in Water and Sediments of the Arabian Sea | Ph.D. (2012) | GSDN |
| 30 | Goyal S. K. | Scientist/Engineer-SE | Electronics & Communication | M.Tech. (2019) | PSDN |
| 31 | Guharay A. | Reader | Atmospheric Physics | Ph.D. (2010) | SPASC |

| Sr. No. | Name | Designation | Specialization | Academic Qualification | Division |
|---|---|---|---|---|---|
| 32 | Gupta G. R. | Reader | Solar Astrophysics Region and Corona, Mhd Waves, Small-Scale Transients, Solar Spectroscopy | Ph.D. (2011) | USO |
| 33 | Jain N. | Scientist/Engineer-SD | Elect.& Comm. Engg. | (2002) | USO |
| 34 | Janardhan P. (FNA) | Senior Professor (H grade) & Dean (up to Feb.'20) | Solar Radio Astronomy & Space Weather | Ph.D. (1991) | A&A |
| 35 | Jani R. A. | Scientist-SE(Tech.) | Paleoclimate and Application Of Stable Isotopes In Hydrology | M.Sc. (1988) | GSDN |
| 36 | Joshi B. | Asso. Professor | Solar Physics, Astronomy | Ph.D. (2007) | USO |
| 37 | Joshi V. | Scientist-SD | Observational Astronomy | Ph.D. (2014) | A&A |
| 38 | Konar P. | Asso. Professor | Particle Physics | Ph.D. (2005) | THEPH |
| 39 | Kumar B. | Asso. Professor | Solar Physics | Ph.D. (2007) | USO |
| 40 | Kumar P. | Scientist/Engineer-SE | Laser Matter Interactions, Spectroscopy & Payload Development | B.Tech. (2011) | AMOPH |
| 41 | Kumar S. | Asso. Professor | Aquatic and Terrestrial Biogeochemistry | Ph.D. (2004) | GSDN |
| 42 | Kumar V. | Scientist/Engineer-SD | Physical Science | B.Tech. (2013) | AMOPH |
| 43 | Kushawaha R. K. | Reader | Atomic Physics | Ph.D. (2009) | AMOPH |
| 44 | Laskar A. H. | Reader | Stable and Radioactive Carbon in Indian Soils: Implications to Soil Carbon Dynamics | Ph.D. (2012) | GSDN |
| 45 | Louis R. E. | Reader | Sunspot Fine Structure, Photospheric-Chromospheric Coupling, Eruptive Phenomena, Post-Focus Instrumentation | Ph.D. (2011) | USO |
| 46 | Mahajan N. | Professor | Particle Physics | Ph.D. (2004) | THEPH |
| 47 | Mahajan R. R. | Scientist-SF(Tech.) | Noble Gas Isotopes, Meteorites | M.Tech. (1997) | PSDN |
| 48 | Mahirale V.K. | Engineer-SG | Civil Engg. | B.E. (1982) | CMDV |
| 49 | Manke A. A. | Scientist/Engineer-SD | Computer Science | M.Tech. (2013) | SPASC |
| 50 | Marhas K. K. | Professor | Solar System Studies | Ph.D. (2001) | PSDN |
| 51 | Mathew S. K. | Professor & Dy. Head (Technical) | Solar Magnetic & Velocity Fields | Ph.D. (1999) | USO |
| 52 | Mathur S. N. | Technical Officer-E | Mechanical Engineering | Dip. In Mech Engineering (1982) | A&A |
| 53 | Mehta D. | Scientist/Engineer-SD | Web Applications Development & Cyber Security | M.Tech. (2013) | ADMDN |
| 54 | Mishra H. | Senior Professor & Chair, THEPH | Strong Interaction Physics & Fields Nuclear Astrophysics | Ph.D. (1994) | THEPH |
| 55 | Mishra H. D. | Scientist/Engineer-SD | Computer Science and Applications | M.C.A (2003) | COMSR |
| 56 | Mishra S. K. | Reader | Complex (Dusty) Plasma Kinetics | Ph.D. (2009) | PSDN |
| 57 | Mithun Neelakandan Ps | Scientist/Engineer-SD | Physical Science | B.Tech. (2014) | A&A |
| 58 | Mohanty S. | Senior Professor (H grade) | Astroparticle Physics | Ph.D. (1989) | THEPH |
| 59 | Naik S. | Professor | High Energy Astrophysics, X-Ray Binaries | Ph.D. (2003) | A&A |
| 60 | Nishtha A. | Librarian-SF | Library & Information Sciences | Ph.D. (2012) | LIBSR |
| 61 | Ojha N. | Scientist-SD | Tropospheric Chemistry and Climate Change | Ph.D. (2014) | SPASC |
| 62 | Pabari J. P. | Engineer-SF | Planetary and Interplanetary Dust | Ph.D. (2011) | PSDN |

| Sr. No. | Name | Designation | Specialization | Academic Qualification | Division |
|---|---|---|---|---|---|
| 63 | Padhya V. K. | Scientist/Engineer-SD | Computer Science | M.Tech. (2013) | GSDN |
| 64 | Pallamraju D. | Senior Professor & Chair, SPASC, Dean (From March 2020) | Space Weather and Atmospheric Coupling Processes | Ph.D. (1997) | SPASC |
| 65 | Panda D. K. | Scientist-SE(Tech.) | Nuclear Instrumentation & Remote Sensing | Ph.D. (2019) | PSDN |
| 66 | Parmar V. M. | Scientist/Engineer-SE | Electrical Engineering | B.E. (2002) | CMDV |
| 67 | Patel A. R. | Scientist/Engineer-SD | Fpga, Payload Hardware Design and Testing | M.E. (2010) | PSDN |
| 68 | Patel K. | Reader | Physics Beyond The Standard Model | Ph.D. (2012) | THEPH |
| 69 | Patel S. H. | Medical Officer-SF | Medicine | M.D (1999) | DISSR |
| 70 | Rajesh T. A. | Scientist/Engineer-SF | Aerosol Characterization and Instrumentation | Ph.D. (2019) | SPASC |
| 71 | Rajpurohit A. S. | Scientist-SD | Astronomy & Astrophysics | Ph.D. (2013) | A&A |
| 72 | Ramachandran S. | Senior Professor | Aerosols, Radiation & Chemistry- Climate Interactions | Ph.D. (1996) | SPASC |
| 73 | Rastogi N. | Asso. Professor | Atmospheric & Aerosol Chemistry | Ph.D. (2005) | GSDN |
| 74 | Raval J. | Scientist/Engineer-SF | IT/Cyber Security, Linux System Administration, Network Administration | M.Tech. (2006) | COMSR |
| 75 | Ray D. | Scientist-SD | Marine Geology & Igneous Petrology | Ph.D. (2009) | PSDN |
| 76 | Ray J. S. | Senior Professor | Isotope Geochemistry | Ph.D. (1998) | GSDN |
| 77 | Sahoo B. K. | Professor | Atomic Physics | Ph.D. (2006) | AMOPH |
| 78 | Sahu L. K. | Asso. Professor | Atmospheric Science, Trace Gases | Ph.D. (2005) | SPASC |
| 79 | Samal M. R. | Reader | Massive Stars and Young Clusters: Formation, Evolution, Feedback Effects, and Associated Interstellar Medium | Ph.D. (2011) | A&A |
| 80 | Samanta G. K. | Asso. Professor | Laser and Nonlinear Optics | Ph.D. (2009) | AMOPH |
| 81 | Sarkar A. | Reader | Mhd Simulation & Solar Physics | Ph.D. (2005) | A&A |
| 82 | Sarvaiya T. N. | Scientist/Engineer-SE | IT Security Virtualization, Sys. Adm. & Networking | M.S. (2014) | COMSR |
| 83 | Seth S. | Reader | QCD, Precision Calculation | Ph.D. (2014) | THEPH |
| 84 | Shah A. B. | Engineer-SG | Automation, Robotics, Payload Development & Fpga | B.E. (1984) | A&A |
| 85 | Shah M. | Scientist/Engineer-SE | Automation, Robotics, Payload Development & Fpga | M.Sc. (2015) | GSDN |
| 86 | Shah R. R. | Engineer-SG | Instrumentation & Control, Data Acquisition, Telescope | B.E., M.B.A. (1997) | A&A |
| 87 | Shah V. M. | Technical Officer-E | Electronics | Dipl. In Electronics & Engineering (1982) | A&A |
| 88 | Shanmugam M. | Engineer-SF | Space Instrumentation and Study of Semi-Conductor Devices/Asics | Ph.D. (2017) | PSDN |
| 89 | Sharma S. K. | Asso. Professor | Middle Atmosphere & Long Term Atmospheric Changes | Ph.D. (2010) | SPASC |
| 90 | Sheel V. | Professor & Chair, PSDN | Modelling of Lower Atmosphere | Ph.D. (1996) | PSDN |
| 91 | Shrivastava A. | Scientist/Engineer-SD | Cyber Security, Computer Networking and System Administration | M.Sc. (1998) | COMSR |
| 92 | Shukla A. D. | Scientist-SF | Geochemistry & Cosmochemistry | Ph.D. (2012) | GSDN |
| 93 | Singh A. | Reader | Ocean Biogeochemistry | Ph.D. (2011) | GSDN |

| Sr. No. | Name | Designation | Specialization | Academic Qualification | Division |
|---|---|---|---|---|---|
| 94 | Singh A. D. | Professor | Atomic Physics | Ph.D. (1998) | THEPH |
| 95 | Singh N. | Asso. Professor | Theoretical Condensed Matter and Statistical Physics | Ph.D. (2006) | THEPH |
| 96 | Singh R. P. | Senior Professor, AMOP & Chair, AMOP | Laser Physics | Ph.D. (1994) | AMOPH |
| 97 | Singh R. P. | Scientist/Engineer-SF | Mesosphere and Lower Thermosphere | Ph.D. (2018) | SPASC |
| 98 | Singh S. K. | Professor | Isotope Geochemistry | Ph.D. (1999) | GSDN |
| 99 | Singh V. | Reader | Active Galactic Nuclei and Evolution of Galaxies | Ph.D. (2011) | A&A |
| 100 | Sinha R. K. | Scientist/Engineer-SD | Planetary Remote Sensing, Glaciology & Impact Cratering | M.Tech. (2011) | PSDN |
| 101 | Sivaraman B. | Asso. Professor | Low Temperature Astrochemistry | Ph.D. (2008) | AMOPH |
| 102 | Srivastava M. | Reader | Astronomical Instrumentation | Ph.D. (2012) | A&A |
| 103 | Srivastava Nandita | Senior Professor & Dy. Head (Administration) | Solar Physics | Ph.D. (1994) | USO |
| 104 | Srivastava Neeraj | Scientist-SE | Planetary Remote Sensing | Ph.D. (2014) | PSDN |
| 105 | Sudheer A. K. | Scientist-SF | Chemistry | Ph.D. (2018) | GSDN |
| 106 | Upadhyay N. K. | Scientist/Engineer-SE | Mechanical Engineering | M.Tech. (2008) | PSDN |
| 107 | Vadawale S. V. | Professor | High Energy Astrophysics and X-Ray Spectroscopy | Ph.D. (2003) | A&A |
| 108 | Vaghela H. R. | Engineer-SF | Mechanical Engineering and Finance | B.E. (1996), M.B.A. (2002) | WORSH |
| 109 | Vaishnav B. G. | Scientist/Engineer-SE | Atomic & Molecular Physics | Ph.D. (2008) | ADMDN |
| 110 | Venkataramani S. | Scientist-SG(Tech.) | Atmospheric Physics | M.Sc. (1986) | SPASC |
| 111 | Vijayan S. | Reader | Planetary Remote Sensing | Ph.D. (2013) | PSDN |
| 112 | Wairagade S. S. | Scientist/Engineer-SF | Civil Engg. | B.E. (1993) | CMDV |
| 113 | Yadava M. G. | Scientist-SG | Palaeoclimate, Radiocarbon Dating and Stable Isotopes | Ph.D. (2003) | GSDN |


पी.आर.एल. में गतिविधियां
Events at PRL
अंतरराष्ट्रीय महिला दिवस समारोह
International Women's Day Celebration
स्वच्छता पखवाड़ा
Swachhta Pakhwada
भौतिक अनुसंधान प्रयोगशाला
Physical Research Laboratory
अहमदाबाद, Ahmedabad
हिन्दी पखवाड़ा समारोह
भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद
विक्रम साराभाई
नवप्रवर्तन प्रतियोगिता
विज़न - 2019
Vikram Sarabhai
Innovation Competition
VISION – 2019

# पी.आर.एल. में गतिविधियां
# Events at PRL









पी.आर.एल. में गतिविधियां
Events at PRL
Indian Planetary Science Conference - 2020
भारतीय ग्रहीय विज्ञान सम्मेलन - 2020
Physical Research Laboratory
Ahmedabad - 380 009


*"The strength of an organization can be judged by how well it can rid calamities. "*

*-Dr. Vikram A. Sarabhai*