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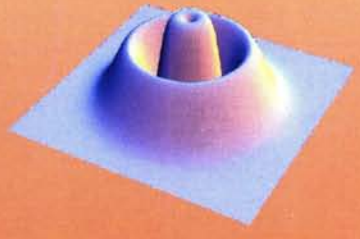
2004-2005



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Physical Research Laboratory, Ahmedabad

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Introduction

Physical Research Laboratory is a premier institute engaged in basic research in experimental and theoretical physics and earth, planetary and atmospheric sciences.

An important milestone crossed this year was the successful completion of ten years of operation of the 1.2meter telescope at the Mt. Abu Infrared Observatory. To mark this occasion a national symposium on *Infrared and Optical Astronomy at Mt. Abu Observatory : The Past Decade and the Future* was held at PRL, during December 15-17, 2004. Inaugurated by Prof. U.R. Rao, the symposium was attended by leading scientists from different institutes in the country engaged in research in the field of astronomy and astrophysics. Major scientific results obtained by PRL scientists during the last decade which made significant impact in national and international scientific forum were presented in the symposium. Some amongst them are : (i) identification of the eruptive variable V445 Puppis as the first observed Helium nova ; (ii) the velocity field in the Lagoon nebula, a bright nearby HII region, indicating a dissipation of shock wave passing through the region and possible slowing down of the star formation rate; (iii) some major features of planetary nebulae like the interaction of NGC 246 with interstellar medium, quadrupolar morphology in NGC 4361 and common envelope ejection in NGC 1514; (iv) detection of jets in young stellar object RNO 91 and clustered star formation in the dark cloud L1340 suggesting massive star formation by accretion rather than coalescence; (v) presence of circumstellar dust shell around the supergiant TV Gem and circumstellar dust structures around carbon star IRC +10216 and Wolf-Rayet star WR 104; (vi) the detection of an extended bright phase in BL lac object PKS 0716 + 714, an active galactic nuclei (AGN) with several outbursts lasting for a few days. The proceedings of the symposium have been brought out as a Special Issue of the Bulletin of the Astronomical Society of India.

The study of the two unique eruptive variable stars V838 Mon and V4332 Sgr using the Mt. Abu infrared telescope, has led to a significant result, namely, the detection of water ice absorption band and carbon-monoxide emission bands, suggesting that these objects define a new class of variable stars. A multi-wavelength study of these two objects has been initiated through several international collaborations using both ground based and space borne facilities such as the UK Infrared Telescope, the Very Large Telescope of European Southern Observatory and the Spitzer Space Telescope.

PRL's Low Energy X-ray Payload of SOXS mission, onboard the Indian spacecraft GSAT-2 has so far monitored more than 300 solar flares. The high spectral resolution data unambiguously resolved Fe lines at 6.7 keV and Fe/Ni line features at 8 keV during solar flares. Analysis of these X-ray spectra revealed that Fe/Ni line features is formed in the solar flares when the temperature reaches around 15 million degree Kelvin.

Two rocket flights were conducted during 2004-05 as a part of a campaign to understand the role of turbulence in producing Mesospheric - Stratospheric - Tropospheric (MST) radar echoes. The rockets carried Langmuir probes and spherical ion probes to determine the turbulence parameters. During the first flight, conducted on July 23, 2004, strong mesospheric echoes were observed in the altitude range 75-77km, both by the rocket borne probes and the MST radar. A very strong correlation between the amplitude of irregularities observed by the rocket and the strength of MST radar echoes was found. The second rocket flight was conducted in April 2005 and analysis of data is in progress.

PRL participated in a major way in the second ISRO-GBP Land Campaign conducted during December 1-31, 2004 in the North Indian region. Eighteen institutes participated in this campaign. The aim was to measure levels of aerosols, their physical and chemical properties and concentration of trace gases such as ozone, carbon monoxide and oxides of nitrogen, and their transport in this region. Episodes of high concentration of trace gases were observed at Hisar as well as at Kanpur during December 2004. Simultaneous measurements of aerosol mass concentration and aerosol optical depth (AOD) using a sun-photometer was also made during this campaign. These data alongwith data obtained by the MODIS (Moderate Resolution Imaging Spectroradiometer) satellite data are being analysed.

PRL also participated in a major way in the second ISRO-GBP Ocean campaign conducted during

December 2004 in the Northeastern Arabian Sea. Five institutes participated in this campaign that lasted three weeks. The aim was to measure physical, chemical and biological ocean parameters during pre-bloom conditions. Experiments were conducted to measure sea surface temperature, sea surface salinity, light attenuation, dissolved nutrients (nitrate, ammonia, phosphate and silicate), photosynthetic fixation of carbon dioxide by marine phytoplanktons using radiocarbon tracer.

A new dating technique, using ^{21}Ne as a time marker that has the potential to be used as a thermochronometer, has been developed and its application demonstrated by analysing a carbonatite sample from Southern India. ^{21}Ne is produced in terrestrial samples by the nuclear reaction $^{18}O(\alpha,n)^{21}Ne$ induced by the alpha particles from the decay of U and Th present in these samples.

PRL in association with ISRO Satellite Centre will design and fabricate one of the baseline payload, the High Energy X-ray Spectrometer (HEX), of the Chadrayaan -1 mission. PRL scientists are also shouldering major responsibility to ensure maximum science return from this mission to further our understanding of the origin and evolution of the Moon.

The most eagerly awaited astronomical phenomenon in recent years, namely, the Venus transit took place on June 8, 2004 after a gap of 122 years and was witnessed by a large number of people at the PRL campus at Ahmedabad, Gurushikhar Observatory at Mt. Abu and Udaipur Solar Observatory at Udaipur. Special arrangements were made for viewing this event and all the three campuses were opened for the public. All through the day visitors kept coming to view the Venus transit in all three campuses and one could see the excitement on their faces.

A summary of scientific achievements is given on page 5. A total of *one hundred and twenty two* papers have been published in high impact journals, of which *one hundred and twelve* were in international journals. About a dozen papers have been selected for inclusion in the prestigious Virtual Journals of Quantum Information, Ultrafast Science and Biological Physics Research and half a dozen publications are cited as significant work done in Astronomy and Astrophysics during the year in an annual review in Publications of Astronomical Society of Pacific. During the year, our scientists participated actively in many national and international conferences with large number of significant presentations, out of which *one hundred and seven,* were invited talks. At present, PRL has *forty one* research scholars and *eighteen* post-doctoral fellows besides other visitors working in various disciplines. *Ten* Ph.D. and *ten* M.Tech theses were submitted (details given in p 30).

Several of our scientists have been honoured with national and international awards. These include the prestigious *Farouk El Baz Award; Hari Om Ashram Prerit Vikram Sarabhai Research Award; Young Scientist Award; Fellowships of the American Geophysical Union; Third World Academy of Sciences and National Academy of Sciences.*

Prof. Stuart Ross Taylor from Australian National University, Canberra, Australia, visited PRL as the twenty fifth Vikram Sarabhai Professor. Besides interacting with students and scientists, he delivered a series of technical lectures as well as a public lecture on *Cosmochemistry of the Early Solar Nebula and Evolution of the Planets*.

Prof. R. V. Krishnamurthy from Western Michigan University, USA, visited PRL and delivered the twentieth Prof. K. R. Ramanathan Memorial Lecture on *Natural and Anthropogenic Controls on Dissolved Inorganic Carbon in the Geosphere*.

Dr. K. Kasturirangan, Member, Rajya Sabha and Director, National Institute of Advanced Studies, Bangalore visited PRL and delivered the Foundation Day Lecture on *My Years as Chairman, ISRO.*

The laboratory honoured eight distinguished scientists with *the Shri Hari Om Ashram Prerit Vikram Sarabhai Research Awards and the PRL Award* at a function on August 12, 2004. **Prof. U. R. Rao**, Chairman, PRL Council of Management graced the function and gave away the awards. Seven distinguished scientists received the Hari Om Awards and one received the PRL Award.

The *gold medal for the best thesis of the year* was awarded to **Tarak Nath Dey**. This medal was instituted during the Golden Jubilee year of PRL in 1997.

The Fourth UN Postgraduate Course in Space and Atmospheric Science, under the auspices of Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP) was conducted at PRL during August 2, 2004 to April 30, 2005. Nine candidates including six of foreign origin from four different countries joined this course. The curriculum broadly covered the physics of planetary atmospheres and ionospheres, space weather issues, instrumentations in space technology, astronomy and astrophysics. As a part of their educational tour, the participants conducted experiments in Mt. Abu and Udaipur and also saw a launch of a sounding rocket from Thumba Equatorial Rocket Launching Station, Trivandrum. The pilot projects conducted during the course were evaluated by the Department of Physics, Andhra University, Visakhapatnam. The participants were awarded certificates during a valedictory function held on April 29, 2005. Eight participants from the previous three courses completed their theses work and were awarded the M. Tech. degree in Space Sciences by the Andhra University.

The laboratory organises workshops and conferences every year. Three international and two national conferences were held this year. The **International Conference on Perspectives in Astro- and Particle Physics** was held during March 30 - April 3, 2004, to mark the 125th Birth Anniversary of Albert Einstein. The discussions were centered around recent developments in the areas of neutrino physics, gravitational collapse, gravitational radiation and cosmology. The meeting recalled the ever important contributions of Einstein's theories and the new avenues, and the generations of physicists inspired by his ideas.

The **International Conference on Submillimeter Wave Science and Technology** was held on October 13-15, 2004. Active researchers from all over the globe including Japan, France, Russia, China, Germany, UK, USA, and Sweden participated in the deliberations. Indian scientists and engineers from various institutes and universities comprised majority of the delegates. Over fifty oral presentations were made on various current and future scientific missions with subjects spanning from astronomy, atmospheric science to the state-of-the-art detector systems, applications, and antennae systems.

The **Sixth International Conference on Exploration and Utilization of the Moon (ICEUM-6)** was hosted by PRL during November 22-26, 2004. It was sponsored by the Indian Space Research Organisation (ISRO), International Lunar Exploration Working Group (ILEWG), European Space Agency (ESA), Optech Incorporated and Space Age Publishing Company. The venue was the magnificent Darbar Hall of the famous City Palace in the picturesque city of Udaipur. The conference was inaugurated by Dr. A. P. J. Abdul Kalam, President of India. More than one hundred and fifty participants from sixteen countries attended the conference. Over one hundred papers and programs of various space agencies of the world were presented at this conference. The conference focussed mainly on the themes: Science of, from and on the Moon, first Results from ESA's SMART-1 Mission, Chandrayaan-1 and Chang'E Missions, status of LUNAR-A and SELENE missions and future missions to Moon. In addition, there were three Round Table Discussions on Science Questions and Priorities, International Collaboration and Moon-Mars Roadmap, and Technology and Resources Utilization.

The Fifteenth National Conference on Atomic and Molecular Physics was organised from December 20-23, 2004. About one hundred and twenty delegates, including ten from abroad participated. The main topics covered were (i) electron and positron collisions; (ii) ion collisions; (iii) intense fields and multiphoton processes; (iv) photon spectroscopy, photoionisation and photofragmentation; (v) physics with cold atoms and quantum optics; (vi) instrumentation for atomic physics experiments and (vii) applications of atomic and molecular physics.

In addition, the **Fifth Planex Workshop on Moon and Meteorites** was organised at PRL during November 5-10, 2005. Forty one participants were selected, to represent a mixture of M.Sc. students, research scholars, PDFs and some young lecturers belonging to the disciplines of Physics, Chemistry and Earth Sciences. Apart from the lectures, tutorials, discussions and as-

signments, the participants were taken for laboratory visits and Sky Watch at the Thaltej Campus of PRL. A **One day Symposium on Planetary Science Research in India** was held on November 8, 2005 as a part of the Planex Workshop. It consisted of invited review talks, oral presentations by PLANEX/RESPOND funded investigators, contributed oral presentations as well as poster presentations. About sixty participants attended.

The **First SERC School on Nonlinear Dynamics** was conducted in PRL from November 29 to December 18, 2004. Fifty four participants from all over the country were selected to attend the school. The school was divided into two parts. Basic topics from nonlinear dynamics were covered in the first part and some advanced topics were covered in the second part. The basic topics dealt with concepts in nonlinear dynamics such as attractors, equilibrium points, stability, solitons, intermittency, chaos etc. Some mathematical tools were also discussed. The advanced topics included synchronization and control of chaos, classical and quantum chaos, and time series analysis. Special lectures on turbulence, fractal calculus, and computation using chaos were also arranged.

The annual *Respond Review* meeting was held in PRL during 25-26 February, 2005. The meeting reviewed about twenty projects in different areas of space sciences. The RESPOND programme, sponsored by ISRO and administered by PRL provides unique opportunity to scientists in universities and institutions to carry out research projects in space sciences.

As a part of our continuing efforts to promote and encourage college students and teachers in pursuing science, a *Summer Training Programme* for Graduate and Post Graduate students and college teachers in science was held during May - July, 2004. Thirty six undergraduates and post graduates and four college teachers participated in the programme.

A public lecture entitled *Formal Mathematics & Applications to Software Safety and Internet Security* by Dr. Jean-Pierre Jouannaud, Director, Laboratory for Computer Science, Ecole Polytechnic & Professor of Computer Science, University of Paris-South, Orsay, was arranged jointly by the *Embassy of France, Alliance Francaise of Ahmedabad and PRL*.

As a part of implementation and progressive use of Hindi in PRL, **Hindi Fortnight** was celebrated at PRL from September 14 - 28, 2004. The celebrations included word quiz, essay, elocution, Hamara Karya, self written poetry competitions etc. The highlight of the celebration was a **One Day Seminar on Research at PRL**, held on September 14, 2004 where twelve speakers, representing different research areas in PRL participated. The key note address was delivered by Prof. S. Krishnaswami, Acting Director. Prof. J.N. Desai, formerly of PRL, inaugurated the Seminar.

PRL was awarded the Second Prize by the Town Official Language Committee (TOLIC), Ahmedabad for commendable work of implementing the Official Language Policy during 2003-2004.

PRL celebrated the **National Science Day**, in association with the Indian Physics Association (IPA), Ahmedabad Chapter on February 26, 2005. The Science Day was dedicated to teachers and students from high schools. More than five hundred and fifty teachers and students from all over Gujarat attended the celebrations. **PRL Scholarships** from the Aruna Lal Endowment Fund, established by Prof. D. Lal, Honorary Fellow and former Director, were awarded to five students on the basis of their performance in Science Quiz and personal interview.

An *exhibition of research highlights & HRD activities of PRL* was set up in the Pride of India - Indian Science Congress-05 Expo at the Nirma Institute. The exhibition was a part of the activities of the Indian Science Congress. PRL was awarded a *Special Appreciation Certificate* by the organizers.

I take this opportunity to thank all my colleagues including administrative, technical and supporting staff for their cooperation. I also thank Prof. S. Krishnaswami, who officiated as the Acting Director from August 14, 2004. I am grateful to the PRL Council of Management for its guidance and advice.

Director

The research programmes of the laboratory can be broadly grouped as shown in the profile below. Some of the important research contributions are summarised.

Astronomy and Astrophysics

One of the major long term programmes pursued by the division members concerns investigations of star forming regions. As part of this programme, massive star forming regions within molecular cloud have been studied. The massive star forming regions quite often contain compact and ultracompact HII regions - these are HII regions with high emission measures and small spatial sizes. The sites of massive star forming regions in the molecular clouds are opaque to visible light because of dense interstellar dust. However, the considerably reduced extinction of interstellar dust at infrared wavelengths allows imaging studies to infer the morphology of such clouds. The scope of this programme has been enhanced by undertaking radio observations using GMRT facility at NCRA, Pune. The integrated study allows one to investigate the individual embedded sources and also physical properties and kinematics of ionized and molecular gases in the region. The sites of massive star forming regions have usually been selected from the IRAS catalogue. Most often the massive star forming regions have revealed clusters of embedded sources. However, in case of IRAS 21413+5442, the massive star formation appears to have taken place in isolation.

The high angular resolution study of long period variables using lunar occultation technique has resulted in angular size determination of these sources at different photometric phases and spectral bands. The occultation observations of the semi-regular variables χ Gem and μ Gem in near infrared have shown the existence of limited molecular envelopes around these stars.

The near infrared photometric monitoring of blazars showed that two sources, PKS 0716+714 and 3C66A, continued to be in bright phase with intense activity. Brightening by a one magnitude in about four months time interval is observed.

Profile of Scientific Activities

Basic Sciences	Atmospheric Sciences	Planetary & Geosciences
Gravitation Physics & Astrophysics	Upper Atmospheric Studies	Oceanography & Geochemistry
Atomic & Molecular Physics	Lower Atmospheric Studies	Palaeoclimate
High Energy Physics	Laboratory Astrophysics	Hydrology
Astroparticle Physics & Cosmology	Planetary Atmospheres	Evolution of Solar System Objects
Infrared & Radio Astronomy		Cosmic Ray Prehistory
Quantum Optics and Quantum Information		Catastrophic Events in Earth's History
Nuclear Physics		Evolution of Indian Lithosphere
Solar Physics		
Non-linear Dynamics		
Computational Physics		

The continued study of the enigmatic nova-like source V4332 Sgr has resulted in additional unexpected surprises which include the detection of water ice absorption band at 3.05μm and the emission band of carbon-monoxide (CO) at 4.67μm. These detections imply an unusually rich molecular envelope around this star. The members of the division have now successfully obtained observing time on the newly launched Spitzer Observatory to study V838 Mon and V4332 Sgr. The far-infrared photometric and spectroscopic observations from Spitzer Observatory would provide unique information about the light echo around V838 Mon and circumstellar environment around V4332 Sgr.

The high time resolution study of a filament eruption/coronal mass ejection associated with solar flare of high cadence at radio wavelengths has shown gradual onset followed by a rapid acceleration phase. The disruption of large scale coronal magnetic field is the likely cause for this event.

The polarimetric study of comets has been pursued with upgraded polarimeter. Automation and remote control capability has increased the observing efficiency of the polarimeter. The uniform polarisation with strong intensity variation of Comet Neat (2001 Q4) indicated that the dust has uniform characteristics.

In recent years the extreme fluctuations in solar wind like its disappearance have been studied. When the normal solar wind conditions were restored after the disappearance event, a mild geomagnetic storm occurred due to fluctuations in the interplanetary magnetic field. The study of geomagnetic storms associated with severe solar flares exceeding class X10 has shown that an increase of ten fold in solar wind pressure resulted in three fold increase in Kp index.

The astronomical event most widely covered by the media during 2004 viz. the Venus Transit was witnessed by a large number of people at Navrangpura Campus, Ahmedabad and Gurushikhar Campus in Mt. Abu. A good set of digital images covering the event were obtained from Mt. Abu which clearly showed the black drop effect.

Solar Physics

The rare cosmic event of Venus transit of June 8, 2004 across the solar disk was observed from USO, Udaipur, in Hα 6563A. The “blackdrop” effect, observed in white light observations in the historical transit, was found in Hα images also.

Successful implementation of an image stabilization system using a tip-tilt mirror and successful testing of a state-of-the-art solar vector magnetograph are the major achievements of the Udaipur Solar Observatory during the last year. Several interesting scientific results based on USO’s own H-alpha data on the major flares of October/November 2003 were obtained. A new prediction algorithm for geomagnetic activity associated with CMEs was developed, while some innovative uses of helioseismic data for examining the effect of flares on acoustic power using wavelet analysis were also attempted.

Submillimeter Science and Solar X-ray Astronomy

Since the discovery of CO, the basic picture of the star formation process has been sketched. Although CO molecules are 10,000 times less common in molecular clouds than H_2, CO is still the second most abundant interstellar molecule and has strong emission lines. The temperature, density, mass and spatial distribution of the molecular cloud is derived from measurement of brightness of several CO lines. The detail information regarding the heating and cooling mechanism in the star forming region is retrieved from the precise measurement of the temperature of the cloud. Using a combination of data from the NRAO-12m Telescope at the South Pole, the Kitt Peak (Arizona) and the CSO - 10m Telescope, we have studied the most active part of the L134N (Lynds 134 N) dark cloud by using 115. 271GHz, ^{12}CO (1-0) and 330.588 GHz ^{13}CO (3-2) lines. Data were reduced using Continuum and Line Analysis Single dish Software (CLASS). The dynamics of the molecular gas are determined primarily by Doppler shift measurements. These dynamics, when influenced by gravitational fields, can reveal the mass distribution of all matter in the region and help us to understand where the gas came

from, how stars are formed, and what triggered the starburst.

Solar X-ray Spectrometer (SOXS) - Low Energy payload onboard GSAT-2 Indian spacecraft has observed more than 300 solar flares since its launch on May 8, 2003. Predicted soft X-ray emission from Fe and Fe/Ni line features during flares at 6.7 and 8 keV respectively were confirmed by the observations. Our analysis reveals that the Fe line is observed at 8MK temperature while Fe/Ni line appears when temperature exceeds 15 MK. A special software SOXSoft is developed to analyze the high cadence data from the mission.

Theoretical Physics & Complex System

The main activities of the division are in the fields of subatomic physics, physics of the early universe and complex systems. Studies in subatomic physics include atomic and molecular physics, nuclear physics and particle physics. At the beginning the universe was too hot and the average energy per particle was too high. The evolution of the universe in that epoch depends on what the fundamental particles are and how they interact. So the studies of this epoch are intimately related to particle physics models. As the universe cooled down, nuclei started forming and knowledge of nuclear physics became important. Even at present energies, the evolution of the stars is governed by laws of nuclear physics. Knowledge of atomic physics becomes important at the time of formation of atoms in the early universe. At present, studies of element abundances in stars require very good knowledge of the atomic and molecular spectroscopy. Finally, to understand the formation of large scale structures, evolution of the stars and several other nonlinear phenomenon in nature one needs to proceed numerically. This is done by the complex systems subgroup, which specializes in studies of stability analysis and chaos, numerical modeling and signal processing.

During the past few years several exciting results came out from the major experiments in neutrino physics. Theoretical understanding of these results in terms of models of particle physics is carried out by members of the group. Significant contribution is made in establishing the relationship between the smallness of the neutrino masses and the matter-antimatter asymmetry in the universe at the time of nucleosynthesis, which is very important for our existence. The group members have also been studying the consequences of the various neutrino physics experiments. Consequences of the neutrinoless double beta decay in lepton number violating processes have been studied very extensively. It has been pointed out that the observed results on geo-neutrinos can give a bound on the age of the earth.

Another important question in particle physics is CP violation. We have observed CP violation in heavy meson decays. But from cosmological consideration we believe that there should be CP violation in other processes as well. A new approach to look for CP violation in the next generation linear colliders has been developed, which relies on the use of transverse polarization of the electron and positron beams.

The phase diagram of strange-quark matter, relevant for neutron star interior, has been investigated with the possibility of lighter up and down quarks forming the two flavor color superconducting matter. Medium dependence of strange quark mass plays a sensitive role in maintaining charge neutrality condition. It is observed that at zero temperature, the system goes from a gapless color-superconducting phase to BCS phase through an intermediate normal matter phase as density is increased. The gapless modes show smooth behavior with temperature vanishing above a critical temperature which is larger than the BCS transition temperature. Such modes will be of relevance for cooling of neutron stars.

Complex system is an umbrella term used to indicate a collection of simple systems that work in tandem and their collective behavior can be rather complicated. Most common examples range from galaxy formation, evolution of stars, weather, stock markets to social dynamics. As can be expected, the interactions between the components of the complex system are generally nonlinear. Unlike the model paradigm of linear systems, namely the harmonic oscillator, nonlinear systems might under certain conditions exhibit chaotic dynamics. This is the generic behavior of nonlinear systems. Hence, study of complex systems requires an understanding of nonlinear phenomena. In this effort, we are already tread-

ing a path not easily amenable to analytical calculations. Thus a significant computational component is an integral feature in all these studies.

In this subgroup, high dimensional atomic systems are studied as well as economic time series along side the coupled chaotic elements on a lattice called the coupled map lattices, just to name a few. All these systems exhibit complexity and certain generic universal properties. For instance, atomic levels display fluctuation properties modeled by random matrix theory and so do the correlations among the volatility of various stocks listed in large stock markets. Both share similar properties and are independent of details of the system. The research work is directed towards uncovering such interesting properties of complex systems using analytical and computational methods from time series analysis, chaotic dynamics, random matrix theory and much more.

Random matrix ensembles of Hamiltonians generated by random interactions, model many-body chaos in nuclei, atoms, quantum dots etc. It is shown for the first time, for spin-less fermion systems, that these random matrix ensembles are analytically tractable by means of the Wigner-Racah algebra of the unitary group that generates the many particle Hamiltonian matrix ensemble. This result opened up the possibility of analytical studies of two-body random matrix ensembles with spin and other good quantum numbers that characterize many finite quantum systems. In addition to the studies using nuclear models, statistical properties of some rare-earth atoms and also dense interacting boson systems are studied. They go towards establishing that two-body random matrix ensembles are generic for finite quantum systems.

In contrast to the conventional series expressions obtained by using spherical polar coordinates, we have shown that the use of cylindrical polar coordinates enables us to derive compact expressions of the first Born amplitude for some selected sets of transitions connecting an initial arbitrary circular state to a final state of large values of orbital angular momentum and magnetic quantum number. The present expressions remove the difficulties in numerical computation and mathematical analysis that are encountered with the conventional series expressions for Rydberg transitions.

We have been able to derive, for the first time, the correspondence principle formula of Born for the dipole matrix element along the x-axis taken between hydrogenic Stark states starting from the corresponding quantum expression without appealing to any classical or semiclassical arguments.

Quantum Optics & Quantum Information

Major research activities of this group are in the areas of quantum optics, quantum information science, coherent control, Bose-Einstein condensates and cold fermions, classical optics, mathematical physics and light scattering experiments. In the frontier area of quantum computation, a number of results regarding the implementation of various logic gates, vital to any quantum computer, has been obtained. In the area of coherent control, significant results in cavity QED have been obtained. In classical optics, new understanding has been achieved in the area of pulse propagation, optical vortices and beam propagation. Light scattering experiments have been carried out which can be used for extracting various useful properties of a medium. A new pairing method has been demonstrated for ultra-cold fermions. In mathematical physics, use of a novel method of solving linear differential equations has yielded closed form solutions for Heun's equation and Hooke's atom.

In quantum optics, study and use of quantum entanglement and implementation of quantum logic gates in different types of physical systems have emerged as an active area of research. Subtle quantum effects have been utilized for carrying out various logic operations. Making use of Lamb shift, it is shown how to realize controlled-NOT gates. Realization of Toffoli gates is also demonstrated. In quantum optical systems, realization of entangled states like W and GHZ has been carried out. A scheme to obtain the basic two-qubit logic gates such as quantum phase gate and controlled-NOT gate using a detuned optical cavity interacting with a three-level Raman system has also been proposed. These

ideas can be extended to produce multi-particle entanglement, required for a realistic quantum computer.

Verification of the Einstein-Podolsky-Rosen (EPR) "paradox", intimately connected with quantum entanglement, is an experimentally challenging task. A novel scheme of verification is proposed, which uses position- and momentum-correlated atomic pairs that are confined to adjacent sites of two mutually shifted optical lattices. These are entangled via laser-induced dipole-dipole interactions.

Implementation of a nonclassical imaging for a quantum search of trapped ions and its advantage over the classical imaging is demonstrated. The quantum method gives more flexibility and higher precision when the number of ions considered in the chain increases.

A new optical scheme to realize Deutsch-Jozsa algorithm using ac Stark shifts has been implemented. The scheme uses an atomic cell consisting of four-level atoms interacting dispersively with a field. It is shown how one can implement the algorithm by performing proper one-qubit and two-qubit operations.

An algebraic procedure to find the eigenstates of two-charged particles in an oscillator potential is given. This correlated and entangled system is studied from the point of view of quantum information, due to its relevance in quantum dots.

Propagation of Gaussian beams and their generalizations is an important area of research. A closed-form analytic expression for the amplitude distribution of a phase flipped Gaussian (PFG) beam passing through a paraxial optical ABCD system is obtained.

A large cooperative effect involving two-atom two-photon vacuum Rabi oscillations in a high-quality cavity is demonstrated. The effect can be realized either with identical atoms in a bimodal cavity or with nonidentical atoms in a single-mode cavity. It is demonstrated, how spontaneous emission in a cavity can be controlled by the application of a dc field. The method is especially suitable for Rydberg atoms, a system of considerable contemporary interest. It is shown that, two-atom excitation is possible with temporally entangled light.

Using a non-perturbative variational approach, various features of a recently proposed superfluid phase of Fermi matter, known as breached-pair phase, are calculated. A possible realization of this phase in two-component Fermi gases in an optical trap is given. The one loop quantum correction to the magnetic moment of charged particles in a plane is computed in a non-commutative space-time. Potentially observable consequences of a non-commutative background are delineated.

Experimental study of vortex, which carries angular momentum, has currently emerged as a leading research area. For application point of view, it is important to know if the vortex is axial or non-axial. It is experimentally demonstrated that the Wigner distribution can bring out the differences between axial and non-axial vortices.

Making use of the built-in ability of the wavelets for capturing the trends in a data set, in variable window sizes, a method for the characterization of the scaling behavior of non-stationary time series is proposed. As a practical example of its application, wavelet transform used on polarized fluorescence spectroscopic data of human breast tissues could differentiate normal and malignant tissue types.

The influence of the refractive index and size parameter of a scatterer on the depolarization of linearly and circularly polarized light in a turbid medium has been investigated. The influence of the refractive index of the scatterer on the polarization of both linearly and circularly polarized light is rather weak for samples with smaller-sized scatterers. Depolarization effects have been investigated for both circular and linearly polarized light, for a variety of scatterer sizes and concentrations.

Space and Atmospheric Sciences

Extensive measurements of aerosols and trace gases were made during both the ISRO GBP land campaigns conducted in February, 2004 and December, 2004 to study their distributions, transport and transformation. Higher levels of surface ozone specially during the return leg were observed at all the remote stations

between Ahmedabad and Hyderabad covered during the first campaign. Similarly, aerosols measured using the micro pulse lidar (MPL) showed elevated aerosol layers during the return leg. Average concentration of black carbon was observed to be about 2 $\mu g/m^3$ at these stations. The aircraft measurements of aerosols around Hyderabad using the MPL showed that these are confined to the first 2 km height but spread horizontally to large distances. During the second campaign conducted in north India, PRL made measurements of aerosols and trace gases at Hisar, Delhi and Kanpur. Episodes of high concentration of trace gases were observed at Hisar as well as at Kanpur during December, 2004. Simultaneous measurements of aerosol mass concentration and aerosol optical depth (AOD) using a sun-photometer and MODIS (Moderate Resolution Imaging Spectroradiometer) satellite data are used for developing correlations between these parameters and to study the differences in them.

Study of the distribution and budget of trace gases in the tropical tropopause layer (TTL) has been carried out using a 3D chemical transport model of MPIM, Germany. The contribution of advection and chemistry is dominant over convection and diffusion in changing the total mass of many important trace species in the TTL.

A general circulation model of GFDL, USA has been used to investigate the effect of Pinatubo volcanic aerosols on polar winter atmosphere. It is shown that the aerosol induced tropospheric gradient is necessary but not a sufficient factor for making the winter polar stratosphere colder, and that the aerosol induced stratospheric meridional gradient is also required.

Using the Rayleigh lidar data at Mount Abu, as well as the lidar data from NMRF, Gadanki, detailed study of temperature profiles of the earth's atmosphere has been done. Double stratopause layers have been observed with a typical separation of 2-8 km.

Mesospheric turbulence has been studied using rocket borne sensors flown from SHAR on July 23, 2004. Supporting measurements were made using the MST radar at Gadanki, and ionosonde - at SHAR and Thumba. Strong turbulence layers were observed in the mesosphere on this day.

All sky imaging of plasma density changes using air glow emissions at 630.0 nm, 557.7 nm and 777.4 nm has been carried out during February-April for the last 3-4 years from Kavalur. These observations have shown simultaneous occurrences of continuous plasma depletion in these emissions for several hours and on many nights. An evidence of interplanetary electric field on OI 630.0 nm nightglow was observed during a space weather event using a narrow band photometric measurement. Further, the nocturnal variations of 777.4 nm airglow intensity over low latitude revealed a dependence on F-layer movement in contrast to earlier belief.

Recoil ion momentum spectroscopy of dissociative ionisation of CO_2 has been carried out at various electron energies. Two different channels, possibly from two excited states of parent molecule, and various precursors have been identified from this study. Measurement of spectra and evolution features of the laser produced plasma (LPP) by time resolved spectroscopic measurements have been made for aluminium, copper and carbon. Multiple velocity groups in metallic LPP plumes have been observed. The instantaneous velocity is found to show oscillatory behaviour. In contrast to the usual expectation of wake effects in dense media, such effects were seen even under high vacuum conditions.

A photochemical model has been developed at PRL to study the ionosphere of Mars. The preliminary calculation in the Martian ionosphere is carried out by using this model. The calculated results are found in reasonable agreement with observations. Theoretical investigation of the chemistry of the coma of comet Halley has also been done. It is found that at radial distances greater than ~1000 km, the major chemical processes that govern the production and loss of several of the important ions are different from those that dominate at distances below this value.

Planetary and Geosciences

The Martian meteorites called Nakhlites have been found to contain records of elementally fractionated Martian atmosphere, favouring the heavy noble gases. The mechanism of this fractionation process still remains

poorly understood. The significantly low elemental ratios of $^{36}Ar/^{132}Xe$ and $^{84}Kr/^{132}Xe$ for the trapped Mars atmospheric component found in the Martian meteorite MIL 03346 suggest that the primary process responsible for incorporation of Martian atmospheric component caused a more severe elemental fractionation in MIL 03346 than in other nakhlites. Surficial adsorption on sediments, and assimilation of such sediments into the Martian magma seems to be the most plausible mechanism that can explain this fractionation.

Isotopic studies of chondrules from extremely unequiliberated chondrites using ion microprobe technique revealed variations in their initial $^{26}Al/^{27}Al$ abundances indicating the possibility that some of the chondrules have experienced thermal metamorphism in a preparent body environment in the solar nebula.

Studies of recently fallen meteorites in India led to reconstruction of orbital parameters of the Orissa meteorite and also identification of a chondritic meteorite, Kasauli, with an unusually long cosmic ray exposure in the interplanetary space before its fall on the earth.

Nucleogenic ^{21}Ne produced through (α , n) reactions on ^{18}O in U, Th rich minerals can be used as a dating tool. We have demonstrated the application of this method to apatite in carbonatite from Hogenakal, South India. Due to the different blocking temperatures of ^{4}He, ^{21}Ne and ^{136}Xe (fission product), this new dating method together with the conventional U, Th-^{4}He and U-^{136}Xe methods, therefore, offers the potential to estimate cooling histories of large igneous complexes.

Geochronological studies of samples from the eastern and western blocks of the Dharwar craton, that forms a major part of the southern Indian shield, suggest that the prevailing notion that the eastern block is devoid of older crustal components is incorrect and the proposal that the eastern block accreted laterally onto the western block needs reevaluation.

A gravity core raised from the Western Arabian Sea was analysed for paleomonsoon reconstruction. Earlier studies mainly used a single proxy, viz., the abundance of G. bulloides, an indicator of upwelling and therefore, wind strength. This core, has an average sedimentation rate of 7cm/10^3 years and has been analysed with an effective resolution of ~ 300 years. Results revealed the following paleomonsoon variations: At ~15 ka BP monsoon intensification is observed based on the calcareous productivity. Since 15 ka BP to 9 ka BP monsoon strength has remained more or less constant. At ~ 8.5 ka BP monsoon maximum is found based on the maximum calcareous productivity observed in the core at that time. ^{18}O exhibits higher values during the last glacial period in all the three species. The average Holocene-LGM amplitude in $\delta^{18}O$ values are 3.6 ‰ for G. ruber and G. sacculifer and ~2 ‰ for G. menardii. Out of this 1.2 ‰ can be explained by the ice-volume effect. Remaining decrease in the $\delta^{18}O$ values can be due to the changing E-P (evaporation - precipitation) budget. Although the organic matter has undergone degradation, the C/N ratio shows an average value of 8 indicating marine origin of the organic matter.

Fulgurites are the glassy-rods formed on the earth's surface by fusing the grains in sandy deposits when lightning strikes. Fulgurites form in-situ and are commonly found in deserts. It has been demonstrated that fulgurites could be dated using thermoluminescence technique and, that the trapped gases in fulgurites can provide clues to contemporary environmental conditions.

Gypsum is an important climatic marker in dryland studies. However, it has not been possible to date this directly. During the past year direct and indirect methods of dating gypsum, using optical and electron spin resonance methods, have been attempted successfully.

Using the newly established TIMS facility, a comprehensive study of the chemical and isotopic (Sr & Nd) composition of sediments of the Ganga River System has been initiated to trace their sources and determine the spatial variabilty in the erosion rates over the central and western Himalaya. Preliminary results of material balance calculations using Sr, Nd, $^{87}Sr/^{86}Sr$ and $_{Nd}$ show that the river Gandak is the dominant supplier of sediments to Ganga at its outflow.

PLANEX

Measurement of low energy (< 300 keV) emission from the lunar surface due to decay of radioactive nuclides in the U, Th series will be carried out during the Chandrayaan-1 mission to Moon to quantitatively understand the transport of volatiles on Moon. The design and development of the high energy X-ray (HEX) spectrometer to carry out this experiment will be done jointly by the PLANEX group at PRL and Space Astronomy Instrumentation Division at ISAC, Bangalore. PRL will be responsible for developing the detector module, front-end-electronics (FEE) and integration of the final payload by incorporating the other subsystems developed at ISAC. Studies have been conducted to evaluate the response of pixilated Cadmium Zinc Telluride array detectors to be used in the experiment. Design of the FEE is completed and tested at bread-board level. The engineering model is expected to be ready by early 2006.

Low energy lunar continuum in the energy range of interest for the HEX experiment has been estimated using the GEANT software developed at CERN. The results obtained are consistent with those obtained by using another approach at Los Alamos National Laboratory, USA. The low energy continuum below 100 keV depends on the chemical composition of the lunar terrains and may be used to infer the composition of such terrains.

Technical Developments

Upgradation/automation of the Optical Polarimeter

The optical polarimeter developed in-house in early 80s has been extensively used for extragalactic astronomy and comet studies. It has been one of the most productive instruments. It has been modernised to increase the observing efficiency. The eyepieces have been replaced with thermoelectrically cooled CCD cameras to acquire and re-center the source within the apertures very precisely. In addition, changing of the filters and apertures has been computerized using stepper motors. The stand-alone PC-486 class system used earlier has been replaced with embedded PC-104 based system which is mounted as a part of the instrument. The DOS based software has been completely ported to Linux Operating System. Device drivers and instrument control software were written in-house for the Linux platform. The instrument can be controlled over the TCP/IP network from the control room at the observatory. A second CCD camera has been mounted on a stage that allows one to move the CCD around the focal plane in a region outside of the beam used by the instrument. This is to be used for autoguiding of the telescope for observing faint sources requiring long integration times. A picture of the modified instrument is shown **(title cover)**. Regular observations have been started using the new instrument.

Development of an Image Stabilization System for Solar Observations at USO

The resolution of ground based telescopes is limited by the atmospheric turbulence. Adaptive Optics technique is used to correct these aberrations in real-time. An image stabilization system is being developed at USO for solar observations. We use a piezo-controlled mirror for correcting the global tilt of the wave-front and a fast data acquisition system for acquiring the images with a frequency of 1 kHz. We use an Intel Pentium 4 system operating under Linux for estimating the image shifts and giving control signals to the mirror. At present, the control system has a potential of achieving closed-loop correction band-width of 100 Hz. The improvement in RMS image motion lies in the range of 5-15 for correlation tracking mode.

Luminescence Laboratory

A new Luminescence Laboratory has been established at the PRL Thaltej Campus. The laboratory is equipped with an automated Risoe TL/OSL reader for making luminescence measurements on quartz, feldspar and polymineral grain extracts from meteorites and terrestrial sediments. The initial experiments will investigate the rate of decay of natural thermoluminescence in meteorites as a function of temperature to develop methods for determining their terrestrial ages.

Computational Facility

PRL provides state of the art computational facilities to the members. All staff members have access to PCs in the computer center in addition to the PCs installed in offices of all faculty members. These 300 (approx) PCs are connected to the mainframe computer through a gigabit local area network (LAN connecting all buildings by fibre cable spread over about one kilometer with gigabit and 100 Mbps switches), which in turn connects to internet by a dedicated 1 MBPS link. There are about 100 deskjet and laser printers, including color laser printers available to the staff members. Several high power servers are regularly being added to improve the computing power and a much higher power computing facility is being planned by forming clusters of servers and GRID computing. PRL is also in the process of joining the national GRID computing facility - GARUDA, which is a joint venture of C-DAC and ERNET.

Infrastructural Facilities Available

Computer Centre, Workshop, Library, Scanning Electron Microscope, Liquid Nitrogen Plant, Glass Blowing Facility, Radio Carbon Dating Laboratory and Aluminising Facility at Mt. Abu.

Research Opportunities

One of the important aims of the laboratory is to serve as a postgraduate and post-doctoral study centre for physics and earth sciences and to train research students in experimental and theoretical physics. With this in view, PRL offers graduate programme leading to Ph. D. degree. It also provides opportunities for carrying out post-doctoral research (**Fig. 1**).

Training Opportunities

PRL organises extensive summer programmes for students as well as college teachers every year. The purpose is to initiate them to current research activities being pursued at PRL which they can continue even after returning back to their colleges and also motivate them to take up research in basic sciences. Students studying in first year masters degree and final year bachelors degree and teachers teaching in science colleges are considered for participating in this programme. Selected students and teachers visit PRL for two months in summer. The students are given projects under the supervision of a faculty member. At the end of the programme they submit a report on the work carried out by them. PRL also provides project training in computer sciences and application to postgraduate students. It also offers training in electronics and computer engineering to engineering and diploma students (**Fig. 2**).

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

Research and Other Scientific Details

The research work carried out by PRL scientists are published in reputed national and international journals. Few of our scientists are also invited to write review articles in the field of their specialisation.

Many of our scientists attend conferences and symposia at home and abroad where they present their research work. Some are invited to present review papers. Some serve as chairmen and members of scientific committees for organising national conferences and symposia. They are also invited to convene and chair sessions during symposia and meetings. The scientific output during the reporting year is shown in **Fig. 4**.

Conferences / Symposia Convened

The laboratory from time to time convenes symposia, conferences and workshops in different disciplines. Scientists and research students from other institutions and universities are invited to participate. During the reporting year PRL convened the following :

1. International Conference on Perspectives in Astro- and Particle Physics, March 30-April 4, 2004, PRL. (Convenors: A.R. Prasanna and S. Mohanty)

2. 4th Space & Atmospheric Science Course, Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP), August 2004-April 2005, PRL.
(Convenors : R. N. Misra and R. Sekar)

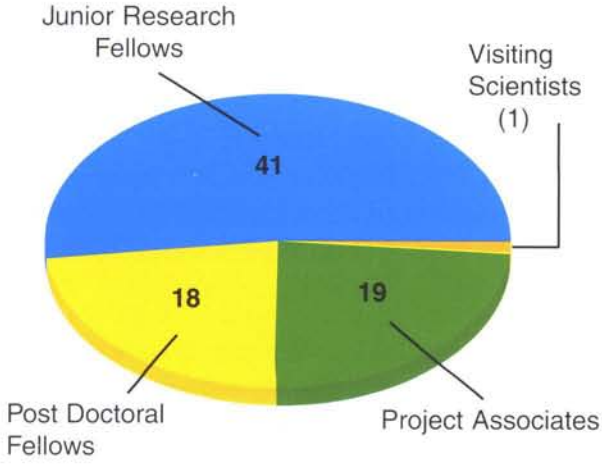

Fig. 1 Doctoral, Post Doctoral and other Programmes

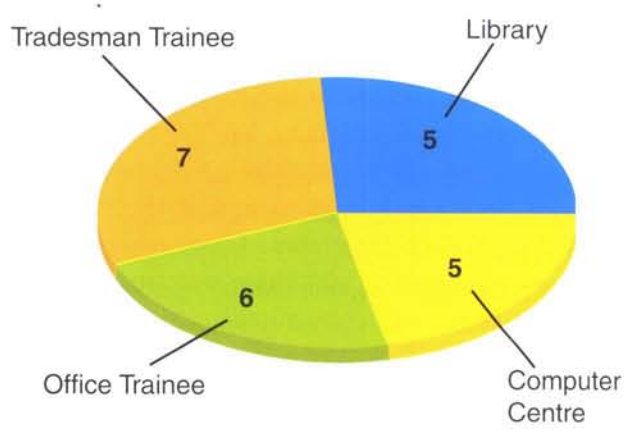

Fig. 3 Training Programme at PRL

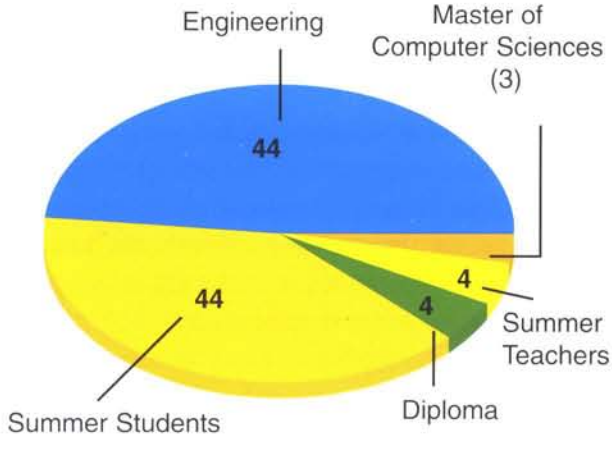

Fig. 2 Graduate & Post Graduate Programme

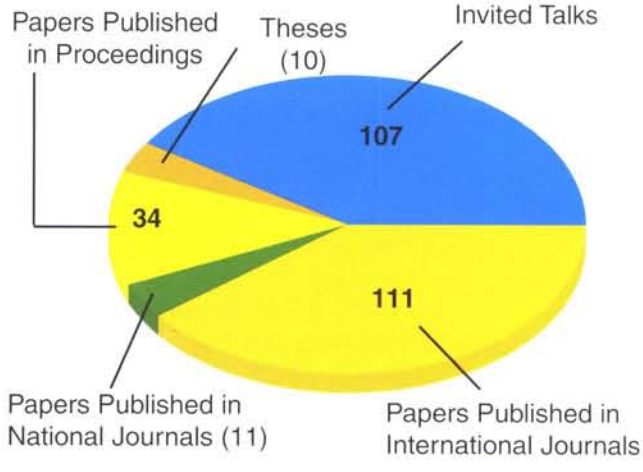

Fig. 4 Scientific Output of PRL

3. International Conference on Submillimeter Wave Science and Technology, October 13-15, 2004, PRL.
(Convenor: Hemant Dave)

4. 5th PLANEX Workshop on Moon and Meteorites, November 5-10, 2004, PRL.
(Convenor : S. V. S. Murty)

5. One day Symposium on Planetary Science Research in India, November 8, 2004, PRL.
(Convenor : S. V. S. Murty)

6. International Conference on Exploration and Utilization of the Moon, November 22-26, 2004, Udaipur.
(Convenors : N. Bhandari and J. N. Goswami)

7. First SERC School on Nonlinear Dynamics, November 29.- December 18, 2004, PRL.
(Course Director : R. E. Amritkar)

8. National Symposium on Infrared and Optical Astronomy at Mt. Abu Observatory : The Past Decade and the Future, December 15-17, 2004, PRL.
(Convenors : B.G. Anandarao and T. Chandrasekhar)

9. 15th National Conference on Atomic and Molecular Physics, December 20-23, 2004, PRL. (Convenors: K. P. Subramanian and Bhas Bapat)

Distinguished Visitors at PRL

Prof. Stuart Ross Taylor from Australian National University, Canberra, Australia, visited PRL as the twenty fifth Vikram Sarabhai Professor and delivered a public lecture on *Cosmochemistry of the Early Solar Nebula & Evolution of the Planets.*

Prof. R. V. Krishnamurthy from Western Michigan University, USA, visited PRL and delivered the twentieth Prof. K. R. Ramanathan Memorial Lecture on *Natural and Anthropogenic Controls on Dissolved Inorganic Carbon in the Geosphere.*

Dr. K. Kasturirangan, Member, Rajya Sabha and Director, National Institute of Advanced Studies, Bangalore visited PRL and delivered the Foundation Day Lecture on *My Years as Chairman, ISRO.*

Seminars and Colloquia Held

The laboratory has an extensive seminar and colloquium programme. Regular seminars are held by different groups both in PRL and Thaltej campus. Reputed scientists, both from national and international institutions are invited to give seminars and colloquia. In addition, the laboratory organised popular lectures by internationally renowned scientists. The following gives an idea of the seminars and colloquia including popular lectures held at PRL :

Seminars held	150
Colloquia including public lectures held	35

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 provide an excellent management support to carry out our scientific activities. The budget and staff structure of PRL are shown in **Figs. 5 and 6**.

Other Activities

Physical Research Laboratory honoured eight distinguished scientists at a glittering function on August 12, 2004. Prof. U. R. Rao, Chairman, PRL Council of Management graced the function and gave away the **Shri Hari Om Ashram Prerit Vikram Sarabhai Research Awards and the PRL Award**. Seven distinguished scientists received the Hari Om Awards and one received the PRL Award. The scientists who were felicitated with the Shri Hari Om Ashram Prerit Vikram Sarabhai Research Awards for the year 2003 are *Dr. C. Siva Ram Murthy* of the Indian Institute of Technology,

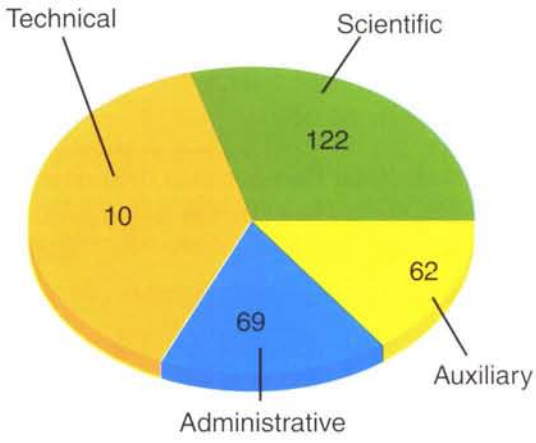

Fig. 5 Staff Structure of PRL

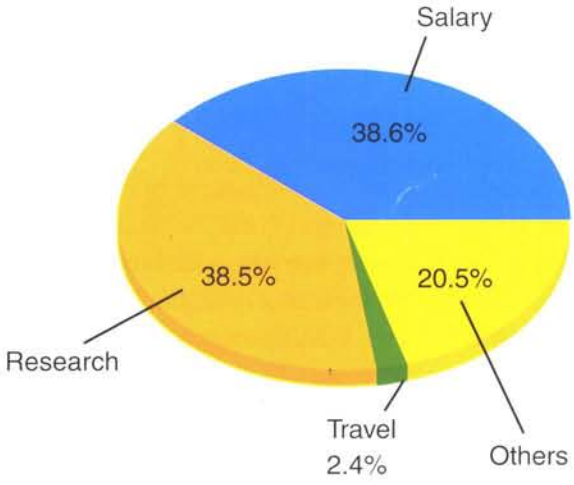

Fig.6 Budget of PRL

Madras; *Dr. P. S. Sastry* of the Indian Institute of Science, Bangalore; *Dr. P. Sreekumar* of the ISRO Satellite Centre, Bangalore; *Dr. P. Janardhan* of the Physical Research Laboratory, Ahmedabad; *Shri Tapan Misra* of the Space Applications Centre, Ahmedabad; *Dr. Y. V. N. Krishnamurthy* of the Regional Remote Sensing Service Centre (ISRO), Nagpur and *Shri M. Annadurai* of the ISRO Satellite Centre, Bangalore. The scientist who received the PRL Award for the year 2003 is *Dr. G. Parthasarathy* of the National Geophysical Research Institute, Hyderabad. The Hari Om Awards were instituted on August 12,1974 in honour of Dr. Vikram Sarabhai, founder of Physical Research Laboratory by the Hari Om Ashram, Nadiad. The PRL Award has been instituted in 1997 from the Aruna Lal Endowment Fund established by Prof. D. Lal, Honorary Fellow and former Director of PRL. All the awards consist of a medal and a cash prize of Rs.50,000/-.

The Physical Research Laboratory awarded the **gold medal for the best thesis** to *Tarak Nath Dey.* The medal was instituted during 1997, the Golden Jubilee year of PRL.

As a part of implementation and progressive use of Hindi in PRL, the **Hindi Fortnight** was celebrated at PRL from September 14 - 28, 2004. Like earlier years the celebrations included word quiz, essay, elocution, hamara karya, self written poetry competitions etc. The highlight of the celebration was a One Day Seminar on Research at PRL which was held on September 14, 2004 in which twelve speakers, representing different research areas were invited. The key note address was delivered by Prof. S. Krishanaswami, Acting Director, PRL. In his address Prof. Krishnaswami presented his views on Hindi Fortnight and Hindi Seminar and requested the staff members to make use of Hindi in their day to day official work. Prof. J.N. Desai, fomerly of PRL, inaugurated the Seminar. In his opening address, he narrated many interesting events of the past and gave an overview of different research programmes, their evolution and growth in PRL. The seminar was divided in three sessions which covered the human resource development programmes, isotope studies in water bodies in India and in reconstructing monsoonal decadal changes; absorption X-ray on the atmosphere and ionosphere of Mars; forecasting of space weather ; study of comets and Blazars from Mount Abu Observatory ; study of effect of temperature of earth on micro grains present in the atmosphere of Antarctica; study of aerosols by satellites; and sub-millimeter research at PRL.

A Two Day Workshop in Hindi during February 29 - 30, 2005 was held at PRL. Twelve staff members participated in this workshop.

Two Space Glossary Half-day Meetings were held from June 16-18, 2004 at PRL for final editing of the glossary.

PRL was awarded the Second Prize by the Town Official Language Committee (TOLIC), Ahmedabad for commendable work in implementing the Official Language Policy during 2003-2004.

Some PRL members got certificate of appreciation in the All India Essay Writing Competition organised at PRL by the Kendriya Sachivalaya Parishad, New Delhi in November, 2004.

The Hindi section participated in various workshops held by various Departments like NTC, Airport Authority, Food Corporation of India, Income Tax and Doordarshan on different topics including Usage of Hindi in Computers.

PRL celebrated the **National Science Day**, in association with the Indian Physics Association (IPA), Ahmedabad Chapter on February 26, 2005. The Science Day was dedicated to teachers and students from high schools from all over Gujarat. More than five hundred and fifty teachers and students attended the celebrations. Two hundred and seventy four students of Standards IX and X participated in the Science Quiz which formed the main part of the programme. As the year 2005 is being celebrated world-over as World Year of Physics, an interactive quiz on the Life & Work of Einstein was conducted for the teachers. Further highlights of the celebrations included talks on *Einstein Today* by Dr. S. Mohanty of PRL and *Tsunami Samjho* by Dr. J. M. D'Souza of the Community Science Centre, Ahmedabad.

PRL Scholarships from the Aruna Lal Endowment Fund, established by Prof. D. Lal, Honorary Fellow and former Director, were awarded to five students on the basis of their performance in Science Quiz and personal interview. All the five students are to receive Rs.5000/- per year for three consecutive years provided the students continue to study in science stream with high academic record.

At the 92nd Indian Science Congress, the science exhibition put up by PRL and ISRO, received a *special appreciation award.*

Awards and Honours

Professor U. R. Rao has been,

i. awarded Star of India Award by the Vishwabharathy Foundation, Hyderabad.

ii. awarded the Special Award 2004 by the Karnataka Media Academy, Bangalore.

ii. named as one of the Top 10 International Space Personalities by the prestigious Space Magazine, Space News Weekly, August, 2004.

Prof. D. Lal has been elected Fellow of the American Geophysical Union.

Prof. S. Krishnaswami has been

i. elected Fellow of the American Geophysical Union.

ii. invited to be one of the associate editors of the Geochemical Journal.

Professor J.N. Goswami has been,

i. awarded the Kamal Kumari National Award for Science and Technology by the Kamal Kumari Foundation, Assam.

ii. elected as the Fellow of the Third World Academy of Sciences.

Professor A.K. Singhvi has been,

i. awarded Farouk El Baz Award – 2004 for Outstanding Research in Deserts by the Geological Society of America, USA.

ii. awarded National Mineral Award – 2003, for overall contributions to Earth Sciences by the Ministry of Steel and Mines, Government of India.

iii. awarded the Roll of Honor by the Bundelkhand University, Jhansi.

iv. elected as the Fellow of the Third World Academy of Sciences.

v. invited to be the Associate Editor of Quaternary Research, Elsevier Press, USA.

Prof. Janardhan P. has been awarded the Hari Om Ashram Prerit Vikram Sarabhai Research Award for Space Sciences.

Dr. Tarak Nath Dey was honored by the Physical Research Laboratory with the award of the gold medal for the best thesis.

Prof. N. Bhandari has been

i. elected as the President of the International Lunar Exploration Working Group.

ii. conferred the title of "Space Visionary" by the International Society of Space Visionaries.

Prof. A.S. Joshipura elected as Fellow of the National Academy of Sciences, Allahabad.

Prof. Utpal Sarkar has been awarded the Senior Associateship of the Abdus Salam International Centre for Theoretical Physics, ICTP, Italy.

Dr. S. Ramachandran has received an Award from Global Change System for Analysis, Research and Training (START) to conduct research work on aerosol and global change.

Som Kumar Sharma has been awarded the Young Scientist Award by International Association of Geomagnetism and Aeronomy (IAGA).

Dr. J.S. Ray has been

i. elected Fellow of the Geological Society of India.

ii. appointed as Associate Editor of Journal of Earth System Science (Indian Academy of Sciences).

Dr. S. K. Singh has been elected Fellow of the Geological Society of India.

Dr. N. Juyal has been elected Fellow of the Geological Society of India

Dr. M. G. Yadava has been elected Fellow of the Geological Society of India.

Mr. Ravi Bhushan has been elected Fellow of the Geological Society of India.

Best Presentations and Posters

Vikas Singh and S.A. Haider received the best paper award under the category of "Planetary Science Research in India", on November 8, 2004 PLANEX Symposium held at PRL.

Sudeshna Basu received the "Young Earth Scientist Best Presentation" award at a DST organized competition, at Dept. of Geology, University of Madras, Chennai, for presenting her thesis work "Nitrogen and Noble gases in carbonatites of India".

Shreyas Managave received the best presentation award for the paper "Noble gases and nitrogen in Lonar impact glasses " at the one day symposium on "Planetary Science Research in India", at PRL on November 8, 2004.

Manish Tiwari has won the first prize in the "First Prof.R. Ananthakrishnan Memorial Conference on Atmospheric Science, Climate Change and Environmen-tal Studies" held at Indian Institute of Tropical Meteorology, Pune, India, January 2005

Sanjeev Kumar received the first prize for research scholars' presentation at the 11th ISMAS Workshop on Mass Spectrometry held at Shimla, during 7-12, October 2004.

Poster presented by, **Koshy G and T. Chandrasekhar**, "H^+_3 in Jovian Aurora", in Sun and Solar System category at 23rd Meeting of Astronomical Society of India, Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital, February 22 to 24, 2005 got the best poster award.

Talk presented by **S. Dasgupta**, "Implementation of Deutsch-Jozsa algorithm using atomic ensemble and a freely propagating photon", Workshop on Quantum Information, Computation, and Communication, IIT, Kharagpur, West Bengal, India, February 15-18, 2005 had been adjudged as the best presentation.

Poster presented by **A. Biswas**, "Quantum Computation with Neutral Atoms" in XV National Conference on Atomic Molecular Physics, Physical Research Laboratory, Navrangpura, Ahmedabad got the best poster award.

Poster presented by **R. Sridharan, A. Raja Bayanna, Brajesh Kumar, P. Venkatakrishnan and C.U. Keller**, "An Image Stabilization System for Solar Observations", in 23rd meeting of Astronomical Society of India, ARIES, Nainital got the best poster award.

Books/Monographs/Reviews Published in 2004-05

Books/Monographs

1. Arvind Bhatnagar, “Fundamentals of Solar Astronomy”, World Scientific Series in Astronomy and Astrophysics, **6**, (2005).

Review Papers

Theoretical Physics & Complex System

Particle Physics

2. S. D. Rindani, “Higgs Physics”, in Current Perspectives in High Energy Physics: Lectures from SERC Schools, ed. D. Ghoshal, Hindustan Book Agency (2005).

3. A. S. Joshipura, “Current Perspectives in High Energy Physics”, Lectures from SERC Schools, Hindustan Book Agency, ed. Debashis Ghosal (2005).

4. A. S. Joshipura, “Introduction to Models of Neutrino Masses and Mixing” in Perspective in Neutrino Physics, Proc. of Indian National Science Academy, 70, 223-232 (2004).

5. U. Sarkar and H. V. Klapdor-Kleingrothaus, “Implications of Neutrinoless Double Beta Decay”, Perspective in Neutrino Physics, Proc. of Indian National Science Academy, 70, 251-266 (2004).

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118. P.J.Thomas, M.Jain, N.Juyal and A.K. Singhvi, "Factors Governing the Comparison of Single Grain and Small Aliquot OSL Dose Estimates in < 3000 years old River Penner Sands, South India", *Radiation Measurments,* **39**,457-469, (2005).

119. M. G. Yadava and R. Ramesh, "Monsoon Reconstruction from Radiocarbon Dated Tropical Indian Speleothems", *Holocene*, **15**, 48-59 (2005).

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120. D. Dhingra, N. Bhandari, P. N. Shukla, G. Lashkari, S. V. S. Murty, R. R. Mahajan, G. M. Ballabh, G. Parthasarathy and A. D. Shukla, "Spectacular Fall of the Kendrapara H5 Chondrite", *Meteoritics and Planetary Science*, **39**, 121-132 (2004).

121. N. Bhandari, "Scientific Challenges of Chandrayaan-1:the Indian Lunar Polar Orbiter Mission", *Current Science*, **86**, 1489-1498 (2004).

122. B. K. Chattopadhayay, J. N. Goswami, S. V. S. Murty, A. P. Thapliyal, J. B. Ghosh, P. N. Shukla, A. D. Shukla, P. K. Mondal, N. C. Pant and N. Sinha, "Meteorite Falls over India during 2003: Petrographic and Chemical Characterization and Cosmogenic Records", *Current Science*, **88**, 774-778 (2004).

Papers Pub. in Proc. of Symposia/Schools in 2004-05

Astronomy & Astrophysics (2005)

1. N.M. Ashok and D.P.K. Banerjee, "V838 Monocerotis", *International Astronomical Union Circular 8423* (October 2004).

2. N.M. Ashok and D.P.K. Banerjee, "V574 Puppis", *International Astronomical Union Circular 8447* (December 2004).

Solar Physics

3. Ashok Ambastha and H.M. Antia, "Variations in Low-l Solar P-modes with Flare Activity", in *Helio- and Asteroseismology: Towards a Golden Future*, *Proc. SOHO14/GONG 2004 Workshop*, ESA SP-559,Ed. D. Danesy, p. 289 (2004).

4. Ashok Ambastha, S. Basu, H.M. Antia, and R.S. Bogart, "Solar P-mode Characteristics Associated with Superactive-Regions Observed during Oct-Nov 2003", in *Helio- and Asteroseismology: Towards a Golden Future*, Proc. SOHO14/GONG 2004 Workshop, ESA SP-559, Ed. D. Danesy, p. 293 (2004).

Theoretical Physics & Complex Systems

5. K. B. K. Mayya and R. E. Amritkar, "Relative entropy of chaotic dynamical systems", *Proc. of the 22nd International Conference on Statistical Physics (Statphys22)*, IISc, Bangalore, p. 230 (2004).

6. S. Jalan and R. E. Amritkar, "Synchronization of coupled dynamical elements on networks", *Proc. of the 22nd International Conference on Statistical Physics (Statphys22)*, IISc, Bangalore, p. 231 (2004).

7. S. Goswami and R. Rangarajan, "Working Group Report : Neutrino and Astroparticle Physics", *Proc. of the DAE-BRNS 8th Workshop on High Energy Physics Phenomenology (WHEPP -8)*, Pramana, **63**, 1391 (2004).

8. A. Mishra and H. Mishra, "Chiral symmetry breaking color superconductivity and gapless modes in 2sc+s quark matter", *Proc. of 42nd International Winter Meeting on Nuclear Physics*, Bormio, Italy, Ed. I. Iori, Supplement, N.123, pp.124-140 (2004).

9. A. Mishra and H. Mishra, " Color neutral color superconducting quark matter: A variational approach", in *Mesons and Quarks, Proc. of Workshop on Mesons and Quarks*, Eds. A.B. Santra, S. Kailas and R.S. Bhalerao, Narosa Publishing House, 306-320 (2004).

10. V.K.B. Kota, "Fermionic O(8) and Bosonic U(36) Symmetry Schemes for Heavy N = Z Nuclei", in *Symmetries in Science XI*, edited by B. Gruber, M. Marmo and N. Yoshinaga (Kluwer Academic Publishers, Dordrecht, The Netherlands) p.265-290 (2004).

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Planetary and Geosciences

14. S. Basu and S.V.S. Murty, "Nitrogen and noblegases in carbonatites of India", *Proc. of 11th ISMAS Workshop on Mass Spectrometry* (Ed. S.K. Aggarwal & P.G. Jaison) pp 257-261 (2004).

15. S. Basu and S.V.S. Murty, "Deep mantle nitrogen from carbonatotes: Pristine and recycled components", *9th Symposium on Study of the Earth's Deep Interior* (SEDI 2004) pp 90-91.

16. R. Bhushan and S. K. Singh, "Surface distribution of sediments in Bay of Bengal: Implications to its provenance and depositional characteristics", *Proc.*

11th ISMAS Workshop, Simla, Indian Society of Mass Spectrometry, Mumbai, 215-217 (2004).

17. S.K. Gupta and R.D. Deshpande, "Water Outlook for India: Quantifying Hydrological Cycle Components and Their Interactions for Sustainable Development Using Isotopic Studies", *Proc. 2nd APHW Conf.* Vol.II, Singapore, pp.325-326 (2004).

18. S.K. Gupta, "Mathematical Modelling of Groundwater Flow and Mass Transport", *Mathematical Models for Interpretation of Hydrologic Tracer Data* (Eds. A.L. Ramanathan, M. Thangarajan and D.R. Ram) Prashant Publishing Co., New Delhi. pp. 176-185, 2004.

19. N. Juyal, A.Kar, S.N. Rajaguru and A.K.Singhvi, "Chronostratigraphic evidence for episodes of desertification since the last glacial epoch in the southern margin of Thar desert India", *Proceedings of International Conference on Desertification in tne third millennium,* (eds. Al.Alsharan et al), Balkema, 123-130 (2004)

20. S.V.S. Murty, "Nitrogen and noble gas studies in meteorites and planets", *Glimpses of Geoscience Research in India: The Indian report to IUGS 1999-2004* (Ed. A.K. Singhvi & A. Bhattacharya) pp111-114 (2004).

21. Prosenjit Ghosh, S.K. Bhattacharya and Parthasarathi Ghosh, "Atmospheric CO_2 during the late Paleozoic and Mesozoic: Estimates from Indian soils", *A History of Atmospheric CO_2 and its effects on plants, animals and ecosystems* (Eds. J.R. Ehleringer, T. Cerling and M.D. Dearing), Ecological Studies, **177**, pp. 8-34, Springer (2005).

22. R. Ramesh and M. G. Yadava (2004), "Significance of stable isotopes and radiocarbon dating in fluvial environments", *Lecture notes, DST Programme on Fluvial systems* (ed. L. S. Chamyal), Dept. of Geology, M.S. University of Baroda, Vadodara, India, pp.107-149.

23. R. Ramesh, M. Tiwari and Sanjeev Kumar, "Application of stable isotope ratio mass spectrometry: some recent studies", *Proceedings of the 11th ISMAS Workshop on Mass Spectrometry* (ed.s. S. K. Aggarwal and P. G. Jaison), pp.119-126 (2004).

24. N. Rastogi and M. M. Sarin, "Chemical uptake of acidic species by mineral aerosols over a semi-arid region", *IASTA Bulletin*, Kanpur, 186-189 (2004).

25. J.S. Ray, "87Sr/86Sr and 143Nd/144Nd variations in carbonatites and associated silicate rocks", *Proc. 11th ISMAS Workshop on Mass Spectrometry,* (ed.s. S. K. Aggarwal and P. G. Jaison), pp.244-249 (2004).

26. N. Sharma, R.A. Jani and R. Ramesh, "Oxygen isotope studies in an Ice wall near Maitri, Indian Antarctic Station", *Special publication of NCAOR*, Goa, pp 88-95 (2005).

27. K.D. Sharma, Bhishm Kumar and S.K. Gupta, "Advances in Hydrology and Water Resources in India", *Glimpses of Geoscience Research in India, The Indian Report to IUGS 1999-2004*, Indian National Science Academy, New Delhi. pp.1-4, (2004).

28. Sanjeev Kumar, R. Ramesh, S. Sardesai, and M. S. Seshshayee, "Evaluation of carbon fixation potential of the northern Indian Ocean: Relevance to Global Carbon Cycle", *Proceedings of the 11th ISMAS Workshop on Mass Spectrometry* (ed.s. S. K. Aggarwal and P. G. Jaison), pp.266-269 (2004).

29. S.K. Singh, "Erosion in the Himalayan: What do we learn from isotopes", *Proc. 11th ISMAS Workshop, Simla, Indian Society of Mass Spectrometry*, Mumbai, 138-145 (2004).

30. S. K. Singh, "Sr isotope Budget of the Ganga Headwaters", *11th ISMAS Workshop*, Simla, Indian Society of Mass Spectrometry, Mumbai, 230-233 (2004).

31. M. Tiwari, R. Ramesh, R. Bhushan, B. L. K. Somayajulu, A.J.T. Jull and G. S. Burr, "Paleomonsoon records from the western Arabian Sea: Evidence of Aeolian input and Red Sea water inflow", *Proceedings of the 11th ISMAS Workshop on Mass Spectrometry* (ed.s. S. K. Aggarwal and P. G. Jaison), pp.270-273 (2004).

32. M. G. Yadava and R. Ramesh, “Decadal variability in the Indo-Gangetic monsoon rainfall during the last ~2800 years: Speleothem $d^{18}O$ evidence from the Sota cave, Uttar Pradesh”*, Special publication of NCAOR*, Goa, pp.121-133 (2005).

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33. M. Ramakrishna, Sharma, C.N. Umapathy, P. Sreekumar, Manju Sudhakar, Lalitha Abraham, J.N.Goswami, N. Bhandari, M. Shanmugam, D. Banerjee, Y.B. Acharya, D.V. Subhedar and P.C. Agrawal, “High Energy X-ray (HEX) Spectrometer on CHANDRAYAAN-1”*, Proceedings of DAE-BRNS National Symposium on Compact Nuclear Instruments and Radiation Detectors-2005*, pp. 249 (2005).

34. D. Banerjee, J.N.Goswami, N. Bhandari, M. Shanmugam, Y.B. Acharya, D.V. Subhedar, M.Sudhakar, L. Abraham, M.R. Sharma, C.N. Umapathy, P. Sreekumar and P.C.Agrawal, “High Energy X-g ray Spectrometer on Chandrayaan-1 : Science Objectives, Detector Characterization and Payload Configuration”*, Proceedings of DAE-BRNS National Symposium on Compact Nuclear Instruments and Radiation Detectors-2005*, pp. 263-267 (2005).

Theses Submitted during 2004-05

1. **Sarika Jalan**

   Some Studies of Growing Networks with Non-Linear Dynamical Elements, (2004).

2. **Jayendra N. Bandyopadhyay**

   Studies in Quantum Chaos: Entanglement, Decoherence and All that, (2004).

3. **S. Rajesh**

   Studies on the Bay of Bengal Lithosphere Based on Satellite Altimeter-derived Geoid and Gravity Data, (2004).

4. **Sanjeev Kumar**

   Nitrogen Isotope Geochemistry of the Northern Indian Ocean, (2004).

5. **Manish Tiwari**

   Quaternary Geochronology and Paleoclimatology of the Indian Ocean, (2004).

6. **P. Sanyal**

   Isotope Geochemistry of Siwalik Sediments and Signatures of Past Climate Change (2004).

7. **Lokesh Kumar Sahu**

   Ozone and Related Gases in the Lower Atmosphere (2004).

8. **Tarak Nath Dey**

   Subluminal and Superluminal Propagation of Electromagnetic Fields (2004).

9. **A. Biswas**

   Methods for Efficient Population Transfer and Quantum Logic Gates (2004).

10. **Anirban Das**

    Geochemical and Isotopic Studies of Rivers Draining Deccan Basalts (2005).

M. Tech. Theses Submitted

1. **Chandana Peiris, T. (Sri Lanka)**

   "Photometric and Spectroscopic Observation of VW Cephei Eclipsing Binary Star" (August 2000).

2. **Falguni Patadia (India)**

   "Multisatellite Observation of Indian Ocean Tropical Cyclones" (August 2002).

3. **Kalyan Bhuyan (India)**

   "Ionospheric Tomography at Low Latitudes" (May 2002).

4. **Narayan Prasad Chapagain (Nepal)**

   "Total Ozone Measurements over Kathmandu using Brewer Spectrophotometer" (December 2002).

5. **Pawan Gupta (India)**

   "Study on Atmospheric Aerosols by measuring the Aerosol optical depth using Hand Held Sun Photometer " (April 2002).

6. **Vikas Singh (India)**

   "Chemistry of Lower Ionosphere of Mars", (June 2004).

7. **Nirvikar Dashora (India)**

   Estimation of Fried's parameter for Udaipur lake site" (June 2004).

8. **Sumit Kumar (India)**

   "Characterizing X-Ray Emission from Solar Flares using Solar X- Ray Spectrometer (SOXS)"(August 2004).

9. **Harsha S. Kumar**

   "Near-Infrared Studies of Transient Clouds on Titan", (August 2004).

10. **Shivkumar Malapaka**

    "Simulation of an Alternative Scenario for the Formation of the Moon" (September 2004).

Invited Talks Presented in Symposia/Schools in 2004-05

Astronomy and Astrophysics

1. "Enigmatic Solar Wind Disappearance Events - Do We Understand Them?", at *International Solar Workshop on Transient Phenomena on the Sun and Interplanetary Medium*, Aryabhatta Research Institute of Observational Sciences (ARIES), **Nainital**, India, 05-07, April 2005 by **P. Janardhan**.

2. "Resolving the Engimatic Solar Wind Disappearance Event of 11 May 1999", at *First Asia Oceanic Geophysical Society (AOGS) Meeting*, **Singapore**, July 5-9, 2004 by **P. Janardhan**.

3. "Solar wind and the magnetosphere", in *National Planning Workshop for IHY 2007*, July 10-11, 2004, RAC **Ooty** by **Hari Om Vats**.

4. "PRL's Astronomy Programmes and Facilities", in *International workshop on Asteroseismology*, December 6-8, 2004, ARIES, **Nainital** by **Hari Om Vats**.

5. "Optical and Near IR Study of Comets from Mt. Abu", in the *Symposium on Infrared and Optical Astronomy at Mt. Abu Observatory : Past Decade and the Future*, December 15-17, 2004, PRL, **Ahmedabad**, by **U.C. Joshi**.

6. "Imaging Fabry-Perot Spectrometric Studies of Velocity Fields in Gaseous Nebulae", in the *Symposium on Infrared and Optical Astronomy at Mt. Abu Observatory : Past Decade and the Future*, December 15-17, 2004, PRL, **Ahmedabad**, by **B.G. Anandarao**.

7. "Near-Infrared Photometric and Spectroscopic Studies on Star Forming Regions", in the *Symposium on Infrared and Optical Astronomy at Mt. Abu Observatory : Past Decade and the Future*, December 15-17, 2004, PRL, **Ahmedabad**, by **B.G. Anandarao.**

8. "Infrared Study of the First Identified Helium Nova V445 Puppis", in the *Symposium on Infrared and Optical Astronomy at Mt. Abu Observatory : Past Decade and the Future*, Dec. 15-17, 2004, PRL, **Ahmedabad**, by **N. M. Ashok**.

9. "Studies of the peculiar nova V4332 Sgr", in the *Symposium on Infrared and Optical Astronomy at Mt. Abu Observatory : Past Decade and the Future*, December 15-17, 2004, PRL, **Ahmedabad**, by **D.P.K. Banerjee**.

10. "Monitoring of AGNs for Variability from MIRO", in the *Symposium on Infrared and Optical Astronomy at Mt. Abu Observatory : Past Decade and the Future*, December 15-17, 2004, PRL, **Ahmedabad**, by **K.S. Baliyan**.

11. "Lunar Occultations in the Near Infrared : Achievements and Challenges", in the *Symposium on Infrared and Optical Astronomy at Mt. Abu Observatory : Past Decade and the Future*, December 15-17, 2004, PRL, **Ahmedabad**, by **T. Chandrasekhar**.

12. "A Near-Infrared Photometric Study of the Massive Star Forming Region IRAS 21413+5442", in the *Symposium on Infrared and Optical Astronomy at Mt. Abu Observatory : Past Decade and the Future*, December 15-17, 2004, PRL, **Ahmedabad**, **V. Venkataraman**.

13. "Infrared and optical studies of a new class of noave — the use of Atomic & Molecular lines as diagnostics to interpret their nature", *XV National Conference on Atomic and Molecular Physics*, 20-23 December 2004, PRL, **Ahmedabad** by **D.P.K. Banerjee**.

14. "Infrared Studies of Classical Novae and Nova like Objects", *23rd Meeting of Astronomical Society of India*, Aryabhatta Research Institute of Observational Sciences (ARIES),**Nainital**, February 22 to 24, 2005. **by N. M. Ashok.**

Solar Physics

15. "Solar Structure and Dynamics", at *DST Regional Workshops on Venus Transit-2004*: (i) April 1-2, 2004, Western Region, **Mumbai**, (ii) April 29-30, 2004, Eastern Region, **Guwahati** and (iii) May 3-4, 2004, Northern Region, **Simla** by **Ashok Ambastha**.

16. "Observational Techniques and Instrumentation for Venus Transit 2004", May 7, 2004, in a *Workshop on VT-2004,* Nehru Center, Worli, **Mumbai** by **Ashok Ambastha**.

17. "The challenge of predicting the occurrence of intense storms" at *International Solar Workshop*, ARIES, **Nainital**, April 5-7, 2005, by **Nandita Srivastava.**

18. "Three dimensional structure of sunspots" at *Astronomical Society of India Meeting*, ARIES, **Nainital**, February 22 – 24, 2005 by **Shibu K. Mathew.**

19. "The Multi Application Solar Telescope : Status Report" at *National Workshop on Decade of Observations at Mt Abu*, December 16-19, 2004, Physical Research Laboratory, **Ahmedabad**, by **P. Venkatakrishnan.**

20. "Design Activities and Experiments Related to The Multi Application Solar Telescope" at *Astronomical Society of India* meeting, ARIES, **Nainital**, February 22 – 24, 2005 by **P. Venkatakrishnan.**

21. "Magnetic Variability of Solar Active Regions", at *International Solar Workshop*, ARIES, **Nainital,** April 5-7, 2005, by P. **Venkatakrishnan**.

22. "Photospheric, Chromospheric and helioseismic signatures of large flares in Super-active region NOAA10486", *International Solar Workshop*, ARIES, **Nainital**, April 5-7, 2005 by **Ashok Ambastha.**

Submillimeter Science and Solar X-ray Astronomy

23. "Performance and Status of SOXS Low Energy Payload", *Seminar to celebrate the FIRST ANNIVERSARY OF GSAT2 IN ORBIT*, ISAC, **Bangalore**, May 12, 2004 by **Hemant Dave**.

24. "Submillimeter wave Program at PRL, India", Presented at the *First Annual Meeting of the Asia Oceania Geosciences Society*, **Singapore**, July 5-9, 2004 by **Hemant Dave**.

25. "Probing the Molecular Universe with Terahertz", Presented at *2nd International Conference on Microwave, Antennae, Propagation and Remote sensing-ICMARS*, **Jodhpur**, November 23-25, 2004 by **Hemant Dave**.

26. " Submillimeter Wave Science and Technology at PRL and Future Plans", Presented at *ALMA detector workshop*, NAOJ, Mitaka, **Japan**, March 8, 2005 by **Hemant Dave.**

27. "Results of One Year of Observations of Solar Flares Made by Solar X-ray Spectrometer (SOXS) Mission", at *35th COSPAR Scientific Assembly* held in **Paris**, France, 18-25 July 2004, by **Rajmal Jain**.

28. "Impulsive Solar Flares Associated with Coronal Mass Ejections", at *35th COSPAR Scientific Assembly* held in **Paris**, France, 18-25 July 2004 by **Rajmal Jain**.

Theoretical Physics & Complex System

29. "Mean Field Approach for Interacting Boson Models: New Applications": in the *National Workshop on Relativistic Mean Field Theory in Nuclear Physics* held at Institute of Physics, **Bhubaneswar** (India) during July 26-31, 2004 by **V. K. B. Kota**.

30. "Chaos and Random interactions in nuclei": in the *International Workshop on Nuclear Structure Physics at the Extremes: New Directions*, held at Himachal Pradesh University, **Shimla** (India) during 21-24 March, 2005 by **V. K. B. Kota**.

31. "Coupled Dynamics on Networks", *Statphys-Kolkata IV, Complex networks: structure, function and processes*, S. N. Bose National Center for Basic Sciences, **Kolkata**, 22June-1July 2004, by **R. E. Amritkar**.

32. "Synchronization in coupled dynamical networks", *Conference on Perspectives in Nonlinear Dynamics*, IITM, **Chennai**, 11-14 July 2004, by **R. E. Amritkar**.

33. "Role of transverse polarization in constraining new physics", *International Conference on Linear Colliders*, April 19-23, 2004, **Paris**, by **S.D. Rindani**.

34. "Color superconducting strange quark matter", *Plenary Session at International Conference on Physics and Astrophysics of Quark Gluon Plasma*, **Kolkata**, February 7-12, 2005 by **H. Mishra**.

35. "Models of Extra Dimensions", *Workshop Series on Theoretical High Energy Physics*, March 16-20, 2005, IIT, **Roorkee** by **U. Sarkar**.

36. "Changing Character of Chaos in Complex Atom: Nd I, Pm I and Sm I", *XV National Conference on Atomic and Molecular Physics*, Physical Research Laboratory, **Ahmedabad**, December 20-23, 2004 by **D. Angom**.

37. "Introduction to OpenMP", *Workshop on Parallel Computation*, Institute of Mathematical Sciences, **Chennai**, January 7 - 14, 2005 by **D. Angom**.

38. "Derived Data Types in MPI", *Workshop on Parallel Computation*, Institute of Mathematical Sciences, **Chennai**, January 7 - 14, 2005 by **D. Angom**.

Quantum Optics and Quantum Information

39. "Generation and Propagation of Spatial Coherence", *Frontiers in Optics, Annual Meeting of the Optical Society of America*, **Rochester**, October 2004, by **G.S. Agarwal**.

40. "Multiparticle Entanglement", *School and Workshop on Quantum Entanglement, Decoherence, Information, and Geometrical Phases in Complex Systems*, International Center for Theoretical Physics, **Italy**, November 2004, by **G.S. Agarwal**.

41. "Inter Atom Two Photon processes and Quantum Entanglement", *XV National Conference on Atomic &Molecular Physics*, Physical Research Laboratory, Navrangpura, **Ahmedabad**, India December 20-23, 2004, by **G.S. Agarwal**.

42. "Cavity QED for Quantum Entanglement Quantum Information", *Quantum Optics Symposium*, Texas A & M University, **Texas**, January 2005,by **G.S. Agarwal**.

43. "Tomography of Partially Polarised Nonclassical Fields", *Workshop on Polarization and Coherence Properties of Electromagnetic Fields*, University of Central Florida, **Orlando**, May 3-7, 2004, by **G.S. Agarwal**.

44. "Coherence in Fields and Singularities", *Workshop on Polarization and Coherence Properties of Electromagnetic Fields*, University of Central Florida, **Orlando**, May 3-7 2004, by **G.S. Agarwa**l.

45. "Many-particle Quantum Entanglement", *10th International Conference on Quantum Optics*, Minsk, **Belarus**, May 30-June 3, 2004, by **G.S. Agarwal**.

46. "Revival of light in waveguides", *National Conference on lasers and their applications in basic and applied sciences (NCLBAS - 2005)*, Visva-Bharati, **Santiniketan**, January 10 - 13, 2005, by **J. Banerji**.

47. "Wavelet transform and applications", *TPSC Seminar*, Institute of Physics, **Bhubaneswar**, September 20, 2004, by **P.K. Panigrahi**.

48. **Four** talks on **"**Coherent states and quantum computation", *U.G.C. Refresher Course*, Sambalpur University, **Sambalpur**, September 22 - 24, 2004, by **P.K. Panigrahi**.

49. "Wavelet domain differentiation of cancer and normal human breast tissue fluorescence spectra", *National Conference on lasers and their applications in basic and applied sciences (NCLBAS - 2005)*, Visva-Bharati, **Santiniketan** , January 10 - 13, 2005, by **P.K. Panigrahi**.

50. "Photo-association spectroscopy of cold atoms", *XV National Conference on Atomic & Molecular Physics*, Physical Research Laboratory, Navrangpura, **Ahmedabad**, India, December 20-23, 2004, by **B. Deb**.

51. "Optical vortices produced by forked holographic grating and sign of their topological charge", *National Conference on lasers and their applications in basic and applied sciences (NCLBAS - 2005)*, Visva-Bharati, **Santiniketan** , January 10 - 13, 2005, by **R.P. Singh**.

52. "Causality - Recent Experiments and Numerical Simulations", *XV National Conference on Atomic & Molecular Physics,* Physical Research Laboratory, Navrangpura, **Ahmedabad**, India December 20-23, 2004, by **T.N. Dey**.

53. "Implementation of Deutsch-Jozsa algorithm using atomic ensemble and a freely propagating photon", *Workshop on Quantum Information, Computation, and Communication*, IIT, **Kharagpur**, West Bengal, India, February 15-18, 2005 by **S. Dasgupta**.

54. "Enhanced Magneto-Optical Rotation in Driven Atomic System", *XV National Conference on Atomic Molecular Physics*, Physical Research Laboratory, Navrangpura, **Ahmedabad**, India December 20-23, 2004, by **S. Dasgupta**.

55. "Quantum Computation by Dispersive interaction of a Raman like System with Bimodal Cavity", *Summer School on Quantum Communication and Logics*, Cargese, Corsica, **France**, August 16 - 28, 2004 by **A. Biswas**.

56. "Quantum computation by dispersive interaction of a Raman like system with bi modal cavity", *Quantum Information, computation and communication*, IIT, Kharagpur, **West Bengal**, India, February 15-18, 2005 by **A. Biswas**.

Space and Atmospheric Sciences

57. "Aerosol radiative forcing - Present understanding", *India-US Climate Change Studies Meeting*, 26-28 July 2004, **New Delhi**, by **A. Jayaraman**.

58. "Solar radiation, Aerosols and Atmospheric Brown Cloud", (**3 lectures**), *ABC Training School*, 6-14 October 2004, Hanimaadhoo, **Male' Islands**, by **A. Jayaraman**.

59. "Global warming and Climate Change", (**3** lectures), *4th PG Course on Satellite Meteorology and Global Climate -SATMET IV* , 6-8 Dec 2004, at the Space Application Center, **Ahmedabad** by **A. Jayaraman**.

60. "Earth's radiation budget, radiative forcing, climate change, passive and active remote sensing of aerosols", (**3 lectures)**, *Short course on Fluid dynamics, remote sensing and atmosphere ocean modeling*, 9-12 Feb 2005, at the University of Hyderabad, **Hyderabad**, by **A. Jayaraman**.

61. "Trace Gases and their impact on climate", *India-US Conference on Space Sciences, Applications and Commerce*, June 21-25, 2004, **Bangalore**, by **S. Lal**.

62. "Greenhouse gases – role in climate change", *Indo-US Climate Change Science Meeting*, July 26-28, 2004, Manesar, **Delhi**, by **S. Lal**.

63. "Nitrogen cycle: Its role in Climate Change", *Indo-EU Workshop*, Hyderabad University, **Hyderabad**, September 6-10, 2004, by **S. Lal**.

64. "Developments in Ozone Research", *INSA Gujarat Chapter*, Gujarat Council of Science & Technology and Centre for Environment Education, 16 Sept. 2004, PRL, **Ahmedabad**, by **S. Lal**.

65. "Surface ozone over the Indian region", *IASTA International Conference*, IIT, **Kanpur**, November 16, 2004, by **S. Lal**.

66. "Atmospheric ozone chemistry, minor constituents, measurement techniques", *UN-CSSTEAP Course on Satellite Meteorology and Global Climate* , **5** lectures, December 13-17, 2004, SAC, **Ahmedabad** by **S. Lal**.

67. "Theoretical investigations of equatorial Spread F: Indian Efforts", *One-day symposium on Equatorial Ionosphere and Geomagnetic Phenomena – Recent Advances and Future Direction*, held at Department of Physics, Saurashtra University, **Rajkot** on January 5, 2005, by **R. Sekar**.

68. "Variation of middle atmospheric electrical conductivity with solar activity", *35th COSPAR Scientific Assembly*, Paris, **France**, 18-25 July 2004, by **S.P. Gupta**.

69. "Satellite borne techniques to monitor precursors of earthquake", *Workshop on Sensing of Earthquakes from Space*, 15th Feb. 2005, ISAC, **Bangalore** , by **S.P. Gupta**.

70. "Production of Cluster Ions and Long Lived Neutral Cluster Molecules in Laboratory Plasma", *Earth and Planetary Science Joint Meeting - Makuhar*i, **Japan**, May 9-13, 2004 by H. S. S. Sinha

71. "Detection of Hydrated, Cluster And Molecular Ions in Laboratory Plasma Analogous to the Ionospheric D - region", *COSPAR Conference*, Paris, **France**, 18-25 July 2004, by **H. S. S. Sinha**.

72. "Comprehensive study on middle atmospheric thermal structure over a sub-tropical station", at *IAGA/ ICMA Workshop*, 16-19 August 2004, BATH, **UK** by **Som Kumar Sharma**.

73. "Atmospheric Soundings from Mt. Abu", at *Symposium on Infrared and Optical Astronomy*, *Mt. Abu Observatory: the Past Decade and the Future*, 15-17 December 2004, PRL **Ahmedabad/ Mount Abu**, by **Som Kumar Sharma**.

Planetary and Geosciences

74. "Anomalous Isotopic Fractionation in Photochemical Reactions", *11th ISMAS Workshop on mass spectrometry*, **Shimla**, October 7-12, 2004, by **S.K. Bhattacharya.**

75. "Fluvial and Aeolian response to southwest monsoon in Southern Margin of Thar Desert", *ST –SERC school on Fluvial Sedimentology*, M.S.University, **Baroda**, November 15-24, 2004 by **N.Juyal**.

76. "Field lectures and training on fluvial sedimentary Processes and records in south Gujarat", *DST – SERC school on Fluvial Sedimentology*, M.S.University, **Baroda**, November 15-24, 2004 by **N. Juyal**.

77. "Planetary evolution processes", *One day symposium on Planetary Science Research in India*, PRL, **Ahmedabad**, November 8, 2004, by **S.V.S. Murty.**

78. "Evolution of the Indian sub-continental mantle: the story from carbonatites", 15th mid-year meeting of Indian Academy of Sciences, Indian Institute of Sciences, **Bangalore**, July 2-3, 2004, by **J.S. Ray**.

79. "Application of stable isotope ratio mass spectrometry: some recent studies", *11th ISMAS Workshop on Mass Spectrometry*, **Shimla**, 7-12 October 2004, by **R. Ramesh**.

80. "Past climate changes: what do they tell us about the sun earth connection?", *International Heliospheric Year Workshop*, **Ooty**, 10-11, July, 2004, by **R. Ramesh**.

81. "Holocene monsoon reconstruction using stable isotopes of hydrogen, oxygen, and carbon in various natural archives in India", *Workshop on Indian monsoon and climate variability during Holocene*, **Bangalore**, 19-20, May, 2004, by **R. Ramesh**.

82. "Climate change and water resources", *World Meteorological Organization Day Lecture*, SAC (Bopal Campus), **Ahmedabad**, March 22, 2005, by **R. Ramesh.**

83. "Significance of stable isotopes and radiocarbon dating in fluvial and environmental systems", *DST Training Programme on Fluvial systems*, M.S. University of Baroda, **Vadodara**, 17 Nov. 2004, by **R. Ramesh**.

84. "Study of oxygen and isotopic fractionation in tropical clouds and its dependence on droplet size distribution", *International Colloquium on an International network for tropical Atmosphere Research-INTAR*, **Tirupati**, 20-22 Jan. 2005, by **R. Ramesh**.

85. "New methodologies and techniques for ^{234}Th analysis in seawater", *International Meeting on Future applications of 234Th in aquatic ecosystems*, Woods Hole Oceanographic Institution, **Massachusetts** (U.S.A.), August 16-19, 2004 by **M. M. Sarin**.

86. "Seasonal variations of Anthropogenic sulphate and mineral aerosols in the marine boundary layer over the North Indian Ocean", at Woods Hole Oceanographic Institution, **Massachusetts** (U.S.A.), September 14, 2004 by M. M. Sarin.

87. "Chemistry-Climate interaction", (**2 lectures**) at the *Refresher course for College Teachers*, Gujarat University, **Ahmedabad**, February 1-21, 2004, by **M. M. Sarin**.

88. "Luminescence Chronometry of Land records and paleomonsoon reconstructions", *International Workshop on Indian Monsoon and Climate Variability during the Holocene*, **Bangalore**, May 17-18, 2004 by **A.K.Singhvi**.

89. "Luminescence dating –Basic Principles, Applications and Implications", *Geological Society of America, Annual meeting*, **Denver**, USA. Nov. 7-10,2004 by **A.K.Singhvi**.

90. "Luminescence dating and Paleoclimate of Deserts" *Annual meeting of Indian Association of Geomorphologists*, **Pune**, November 29-December 1,2004, by **A.K. Singhvi**.

91. "The Human Dimension of Geosciences", *Annual Meeting of Indian Association of Sedimentologists*, **Chidambaram**, December 21-24, 2004 by **A.K. Singhvi.**

92. "The Human Dimension of Geosciences", *Birbal Sahni memorial lecture*, Birbal Sahni Institute of Paleobotany, **Lucknow**, November 14, 2004 by **A.K. Singhvi**.

93. "The Human Dimension of Geosciences", *Foundation day lecture*, Wadia Insitute of Himalayan Geology, **Lucknow**, June 29, 2004 by **A.K.Singhvi**.

94. "The Human Dimession of Geosciences- the International Geosphere-Biosphere Programme and The International Year of Planet Earth .The L. N. Kalla Memorial lecture", *Indian Society for Remote Sensing*, Space Applications Centre, **Ahmedabad**, March 4,2005 by **A.K. Singhvi**

95. "Understanding Desert Sediments: Processes, Timescales and Societal Implications", *International Seminar on the Precambrian*, Budelkhand University, December 22, 2004**, Jhansi**, by **A.K. Singhvi**.

96. "Luminescence dating of fluvial sediments - basic method and methodological aspects in applications". *DST –SERC school on Fluvial Sedimentology*, M.S.University, **Baroda**, November 15-24, 2004 by **A.K. Singhvi**.

97. "Erosion in the Himalayan: What do we learn from isotopes?", *11th ISMAS Workshop on mass spectrometry*, **Simla**, October 7 -12, 2004 by **S. K. Singh**.

98. "Sr Isotopes in Water System", *DST supported Contact Programme on Isotope Geology and Geochronology: Rb-Sr systematics* at IIT, **Roorkee**, February 5-25, 2005 by **S. K. Singh**.

99. "Use of AMS dates in palaeoclimate research", *AMS User Interaction Meeting*, Institute of Physics, **Bhubaneswar**, August 26-27, 2004, by **M. G. Yadava**.

100. **Plenary lecture** "Past-monsoon reconstruction from stable isotope variations in speleothems from India", *XVII International Symposium on Biospeleology*, Pt. Ravi Shankar Shukla University, **Raipur**, November 25-30 by **M. G. Yadava**.

PLANEX

101. "Chandrayaan-1: Science Goals", *International Lunar Conference / ILEWG 6*, **Udaipur**, November 22-26, 2004, by **N. Bhandari**.

102. "The High Energy X-ray (HEX) Payload on the Chandrayaan-1 Mission", *International Lunar Conference / ILEWG 6*, **Udaipur**, November 22-26 2004, by **J. N. Goswami.**

103. "Early Solar System Processes", *Symposium on Planetary Science Research in India*, Physical Research Laboratory, **Ahmedabad**, November 22-26 2004, by **J. N. Goswami.**

Computer Centre

104. "Linux System Administration", *IEEE Workshop on Linux*, May 15–16, 2004, at DA – IICT, **Gandhinagar,** by **G. G. Dholakia**.

105. “Securing Linux System – I”, *IEEE Workshop on Linux*, May 15–16, 2004, DA – IICT, **Gandhinagar**, by **Jigar Raval**.

106. “Securing Linux System – II”, *IEEE Workshop on Linux*, May 15–16, 2004, at DA – IICT, **Gandhinagar**, by **Subhasis Mahapatra**.

Library

107. “Ejournals Consortia Models”, *UGC’s Refreshers’ Course for Practicing Librarians*, February 9, 2005, at S P University, **VV Nagar** by **Nishtha Anilkumar**.

4th Space & Atmospheric Science Course
Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP)

Physical Research Laboratory, Ahmedabad

August 2004 - April 2005

Name	No. of lectures	Topic
Shyam Lal	10	Basic Concepts of Earth's Atmosphere
A. Jayaraman	10	Solar Radiation and its Effect on Atmosphere
H Chandra	10	Ionospheric Propagation and Measurement Techniques
H. S. S. Sinha	8	Airglow Emissions
S. A. Haider	8	Ionospheres of other Planets and Satellites
Ashok Ambastha	5	Elements of Solar Physics
A. C. Das	10	Magnetosphere of Earth
P. Janardhan	10	Space Weather
Ashok Ambastha	10	Measurement Techniques of Solar & Geomagnetic Parameters
U. C. Joshi	7	Introduction to Astronomy and Astrophysics
B. G. Anandrao	6	Introduction to Astronomy and Astrophysics
D. P. K. Banerjee	10	Astronomical Instruments and Observing Techniques
N. M. Ashok	10	Optical and Near IR Studies of Stars and Galaxies
R. N. Misra	10	Telemetry and Telecommand
Y. B. Acharya	13	Space borne Instrumentation &Lidar Techniques
D. V. Subhedar	3	Reliability Considerations, Test and Evaluation
J. N. Goswami	3	Planex Programme
Rajmal Jain	3	SOXS Experiment
H. Dave	2	Sub millimeter wave Techniques
Bhas Bapat	20	English Language and Orientation

5th PLANEX Workshop on Moon and Meteorites

Physical Research Laboratory, Ahmedabad

November 5-10, 2004

Name	No. of Lectures	Topic
J. N. Goswami	3	General description of the solar system; Indian Moon mission – Chandrayaan-1; Early solar system processes - chronology
S. V. S. Murty	3	Terrestrial Planets; Meteorite ages and their meaning; Interplanetary Dust Particles
P. Janardhan	1	Living with a star – our Sun
T. Chandrasekhar	2	Asteroids and comets; Satellites
D. Banerjee	3	Earth-Moon system; Alpha spectroscopy, Gamma and X-ray fluorescence methods: Applications to chemical mapping of planetary surfaces ; Water on Moon
N. Srivastava	2	Remote sensing of Moon: surface morphology and mineralogy; Cratering history of lunar surface
D. Dhingra	1	SPA and its importance
A. D. Shukla	1	Meteorite collection and classification
M. Shanmugam	1	CdZnTe detectors
R. R. Mahajan	1	Meteorites from planets
G. Rudraswami	1	Nebular and parent body processes
J. P. Das	1	Chondrules
K. Uma	1	Interstellar grains in meteorites
P. N. Shukla	1	Chemistry and chronology of Moon

Science at PRL

Near-infrared Spectroscopy and Spectral Energy Distribution Studies of AGB stars

This programme, started nearly two years ago, involves understanding the equivalent widths of CO ($\Delta v=2$ and $\Delta v=3$) vibrational-rotational bands in K and H bands in terms of the photospheric and circumstellar properties of AGB stars that include Mira (o Ceti) type long term variables, S type cool giants, semi-regular (SR) variables and post-AGB stars that show no signs of variability. Nearly 70 stars have been observed from Mt. Abu Observatory using the NICMOS spectrograph in the region of 1.4 - 2.4 μm (H and K bands). Modeling of spectral energy distributions of these classes of stars is also being done using the code 'DUSTY'. Several interesting results have been obtained - one of them being a strong correlation between period of Miras and SR variables and the [K-12] or [H-K] color indicating the effect of mass loss. Correlations are found to exist between CO (2-0) and CO (3-1) as well as CO (3-0) and CO (4-1) equivalent widths. Attempts are being made to generate synthetic spectra that include CO first and second overtone bands.Three of the post-AGB type stars showed hydrogen Brackett series lines in emission. These stars, classified as Be type, are moving towards the proto-planetary nebula stage.

(B.G. Anandarao, V. Venkataraman and Mary Thomas)

Near-infrared and Radio Continuum Observations of the Massive Young Stellar Object IRAS 21413+5442 and its Environment

As a part of our on-going long-term programme on near-infrared investigations of star forming regions, we have studied the massive young stellar object (YSO) IRAS 21413+5442 and its environment. IRAS 21413 + 5442 is one of the most luminous ($L_{far\text{-}ir} = 3.2 \times 10^5 L_{sun}$) massive YSO with high velocity CO outflow. Earlier near-infrared (NIR) studies elsewhere showed that it is an early pre-mainsequence (PMS) star that is embedded in a nebulosity with water ice feature at 3.1μm in absorption. The earlier radio observations show the HII regions - one surrounding the massive YSO and the other north of it. We made new NIR photometric observations of this object as well as its near environment - especially the IRAS source IRAS 21407+5441 - in the J, H, K' bands using the NICMOS camera at Mt. Abu Observatory. This latter source is identified as an ultra-compact HII region. Narrow band images were obtained at 2.16 μm for Br γ line, 2.12 μm for H_2 S(1)1-0 line and 2.14 μm for continuum. Radio continuum observations were also made in the 1280 MHz band using the GMRT facility near Pune. The field of view covered both the IRAS sources. Attributed to the Bremsstrahlung radiation, the radio continuum yields important physical parameters such as electron density and the extent of the HII region. Our investigation shows that the massive YSO is likely a late O type PMS object. We also identified a few more intermediate mass YSOs in the field. The spectral energy distributions of the two IRAS sources suggest that the objects are heavily obscured by molecular gas and dust. The radio map suggests (see **Fig. 1.1**) that these two sources might have formed from the same parent molecular cloud. This seems to be one of the rare cases of massive star formation in isolation as opposed to clustered formation.

(B.G. Anandarao and V. Venkataraman)

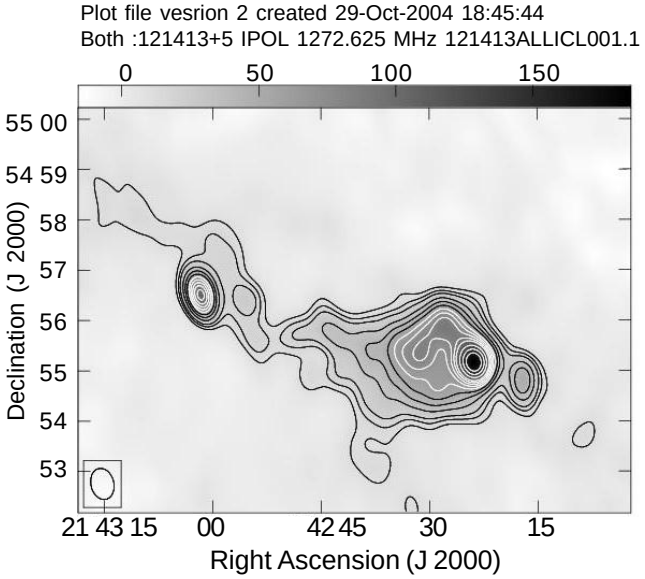


Fig. 1.1 *: Grey scale map of the massive star forming regions IRAS 21413+5442 (intense blob on left) and IRAS 21407+5441 (on the right side) observed at GMRT in the continuum band 1280 MHz.*

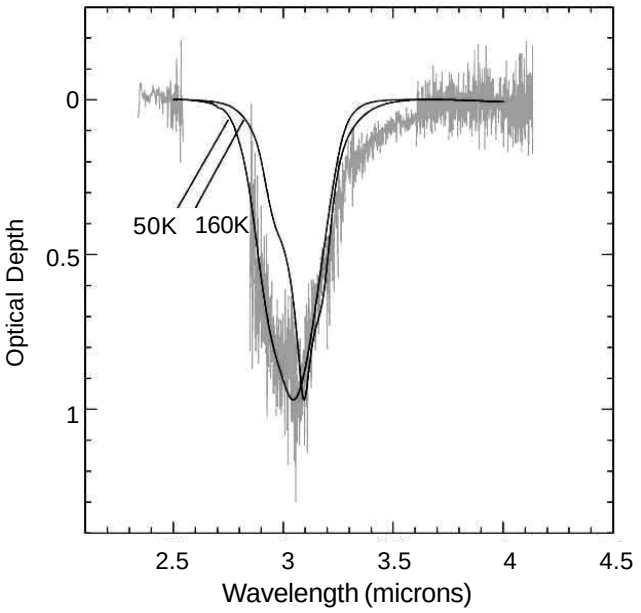


***Fig. 1.2** : The observed and model optical depth plots for the water ice feature seen in V4332 Sgr.*

Studies of the Nova-like Source V4332 Sgr : Detection of Water Ice, Carbon Monoxide and Search for Radioactive ^{26}Al.

The study of the enigmatic nova-like source V4332 Sgr was extended to the 3 to 5 μm spectral region, (L and M bands), resulting in two significant results, namely the detection of water ice absorption feature at 3.05 μm **(Fig. 1.2)** and the fundamental band of ^{12}CO at 4.67 μm in emission. These results further support the view that V4332 Sgr is an interesting object. The presence of cold water ice around V4332 Sgr is unexpected as ejecta of classical novae reach high temperatures of a few million degree Kelvin. The observed optical depth plot of the ice feature was compared with the laboratory data in the 10 to 160 K temperature range with the best fit being obtained for 30 to 50 K data. A column density of N=1.8 x 10^{18} cm^{-2} was obtained and this value will be useful for understanding the ice composition if additional ice (CO_2, CH_3OH, CH_4) is detected in future.

The evolutionary status of V4332 Sgr is not clear at present and also the cause for the nova-like outburst is not well understood. On the basis of our near infrared and optical photometric as well as spectroscopic data we have suggested that there is a good case for V4332 Sgr to be a young stellar object with a surrounding circumstellar disk as most water ice detections are seen towards young stellar objects embedded in molecular clouds and also protostars. A nova-like outburst similar to V4332 Sgr was observed in early 2002 in V838 Mon, and in its case it has been suggested in the literature that the capture of planets by the central star was the cause for the multiple outbursts. The considerable evidence discussed above for a cold dusty disk in V4332 Sgr is a favourable environment for the formation of planets. We suggest that a planetary infall could be responsible for the outburst in V4332 Sgr. The outburst luminosity can be accounted by the capture of Jupiter like planet if the mass of the central star is close to 1 solar mass.

Another rare feature seen in our V4332 Sgr spectra is the fundamental band of ^{12}CO at 4.67 μm in emission. This emission band is seen mostly towards young stellar objects. The model spectra for the ^{12}CO emission were computed for different temperatures and the model fits indicate a low temperature of ~ 300-400 K **(Fig.1.3)**.

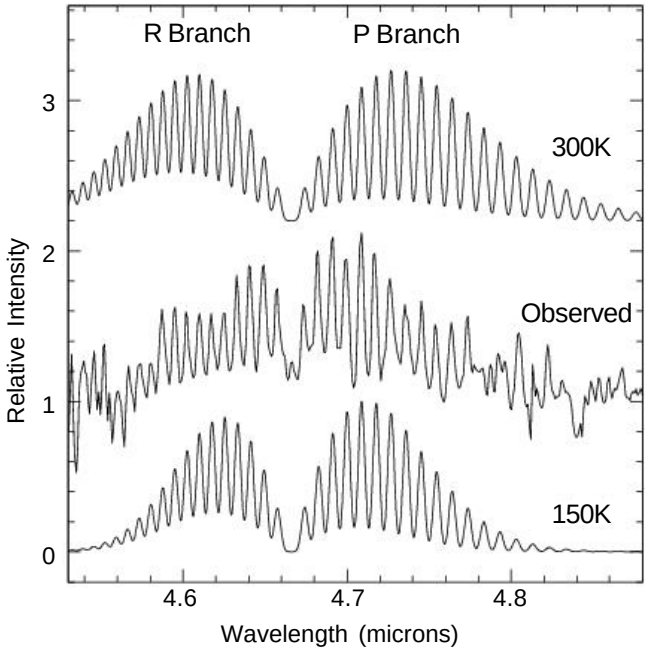


Fig. 1.3 : The observed ^{12}CO fundamental emission bands in V4332 Sgr are shown along with the model spectra. The R and P branch rotational lines are better fit by 300K model.

The molecular bands can be used to study different isotopic compositions as they can be easily resolved spectroscopically at an intermediate resolution. The presence of strong AlO bands in V4332 Sgr offered a unique chance to detect radioactive isotope ^{26}Al, which is an important radioactive isotope for studying galactic radio activity. The nova-like outburst of V4332 Sgr indicated that conditions are favourable for detection of ^{26}Al as the theoretical models predict enhancement of ^{26}Al/^{27}Al ratio in novae. The observed spectrum of V4332 Sgr was compared with a computed model spectrum in the spectral region 1.45 to 1.55μm (taken from UK Infrared Telescope, Hawaii) for pure ^{27}AlO component. The model spectra were computed for different fractional contributions of ^{26}AlO ranging from 0.1 to 1.0 and the statistical tests showed that ^{26}Al is not present at strengths of 15% to 20% and we have put an upper limit of 10%. The lack of ^{26}Al at appreciable strength indicates that the progenitor of V4332 Sgr is unlikely to be ONeMg white dwarf.

(N.M. Ashok and D.P.K. Banerjee)

Near Infrared Angular Diameters of Miras and Semi Regular Variables by Lunar Occultations

Multiwavelength measurements of angular sizes of Miras at different phases of their pulsational cycle provide a direct means of understanding their atmospheric extension and pulsation properties. Large opacities of the atmospheric molecules in some particular wavelength bands mask the dominant photospheric continuum radiation. Consequently photospheric size measurements are affected in the different filter bands for Miras. For Semi Regular Variables (SRV) the situation is not clear. Recent optical/IR interferometric measurements suggest that the dispersion in angular sizes in the near IR J, H and K bands could be a common phenomenon in Miras but that may not be the case for SR variables.

Angular diameter measurements in the near infrared of six evolved variables were obtained by the lunar occultation technique at the 1.2 m Mt. Abu telescope. These include two Miras (U Ari and Z Sco) and 4 semiregular variables including the Supergiant TV Gem (SW Vir, η Gem, μ Gem and TV Gem). Our uniform disk (UD) angular diameter for the Mira U Ari in the K band (2.2/0.4 μm) shows a substantially larger value (~ 20% larger) compared to H band measurements made elsewhere at a similar variability phase. Such enhancements, also seen in recent interferometric measurements, are consistent with a warm extended molecular layer of water vapour (1500-2000 K) close to the photosphere. L' band (3.8 μm / 0.6 μm) occultation observations were also made simultaneously with the K band for U Ari but the L' band data is too noisy for deriving a reliable angular diameter. In case of the two SR Variables η Gem and μ Gem however, reliable angular diameters could be deduced in both the K and L' bands (**Table 1**). For η Gem two lunar occultation events separated by a few months

Table 1 : Infrared Angular Diameters and Derived Effective Temperatures

Star	Type	Photometric Phase	Filter	Ang. Dia(UD) (mas)	T_{eff} (K)
U Ari	Mira	0.57	K	7.3±0.3	2250±80
Z Sco	Mira	0.26	K	3.8±1.0	3120±420
SW Vir	SRb	0.56	K	15.9±0.6	3060±130
η Gem	SRa	Event 1	K	12.7±0.3	3450±125
			L'	12.7±1.0	
η Gem	SRa	Event 2	K	12.8±0.3	
			L'	12.8±2.0	
μ Gem	Lb		K	13.7±0.5	3675±140
			L'	14.8±1.0	
TV Gem	SRc		K	4.8±0.2	3750±120

could be observed in both K and L' bands with consistent results. Both η Gem and μ Gem do not exhibit any enhancement in their L' band diameters unlike in the case of Miras, showing thereby that they do not harbour any substantial molecular envelope. Another result pertaining to SR Variables is the confirmation of the dust shell around TV Gem at a distance of 13 ± 5 R_{star} from its centre. Effective temperatures for all sources deduced from the angular diameters and bolometric fluxes are also shown in **Table 1**.

(T. Chandrasekhar and S. Mondal)

Polarimetric Observations of Comet NEAT (2001 Q4)

Comet NEAT (2001 Q4) was observed using the optical photopolarimeter during the periods May 13 to 20, 2004 and on June 10, 2004 covering a range in phase angles (sun-comet-observer angle) from 86 to 55 degrees. Wavelength dependence peaking beyond the red is observed. On May 20, observations were taken along different locations in the coma of the Comet. Strong variation in intensity is observed, however the polarisation does not change very significantly with location. The inference is that the dust is having nearly uniform characteristics at all the observed locations in the coma.

During May 2004 the comet was at high phase angle (>77^{o}). The polarization at this phase reached 24% to 26% in the R band as shown in accompanying figure **(Fig. 1.4)**. It appears to be slightly lower than the expected polarization simulated from observations of comet Halley. On June 10 (with phase angle ~55 degs) the polarization is close to that expected for Halley and much less than that expected for an extrapolation of observations of Comet Hale-Bopp. The conclusion is that the grain size distribution is relatively larger for this comet than that for Hale-Bopp and perhaps also than that of Halley. However, the comet clearly belongs to the high polarisation class of comets.

(K.S. Baliyan, U.C. Joshi and S. Ganesh)

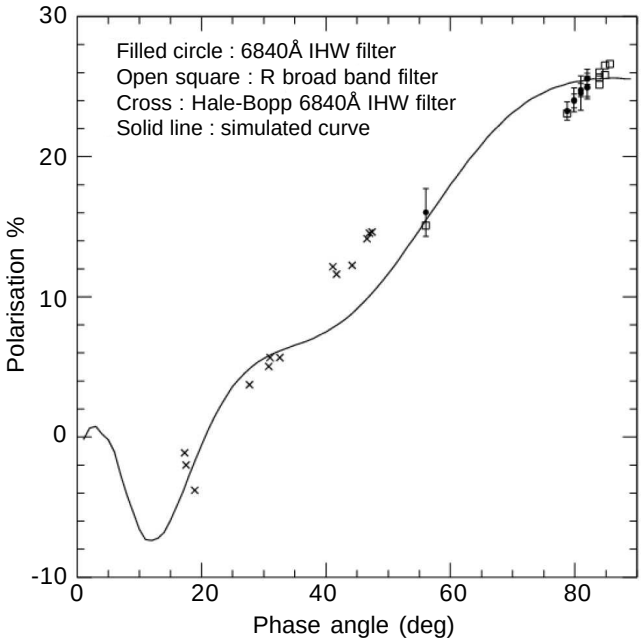


***Fig. 1.4** : Phase dependence of observed polarization for Comet NEAT (2001 Q4) at 6840 angstrom (narrow band International Halley Watch filter) as filled circles; open squares for R broad band filter; crosses denote observations of Hale-Bopp with the 6840 narrow band filter. Solid line is a curve generated by simulation for Halley data.*

Co-ordinated High Energy Gamma-ray and Near Infrared Observations of 1ES2344+514

1ES2344+514 (z = 0.04) is one of the first BL Lac objects to be reported as an extreme synchrotron blazar with synchrotron peak energy reaching up to 100keV. During November-December 2004, source was in active phase and we decided to co-ordinate with BARC's Mt Abu facility to have simultaneous observations in near infrared and high energy (TeV) gamma rays. The source was observed in near infrared J, H & K bands for six nights during November and December 2004, using NICMOS-3 array mounted at the 1.2m IR Telescope of Mt Abu Infrared Observatory (MIRO). Significant variations in near IR flux were noticed during this period. It was also observed by BARC team during October-December 2004, using the imaging element of the TACTIC array at Mt Abu who collected data for 53 hours in on/off mode of observations. Such a study can provide clues to the dominance or

otherwise of the Compton component (ie the Gamma-ray to near IR luminosity ratio).

(K.S. Baliyan, U.C. Joshi and S.Ganesh)

Near IR Monitoring of Blazars PKS0716+714, 3C66A for Variability from MIRO

As a long term program, a sample of blazars is being monitored from Mt Abu Infrared Observatory (MIRO) to obtain information on the geometry of the jets and the physical processes responsible for the high energy emissions. Out of all the blazars monitored last year, PKS0716+714 and 3C66A have shown intense activity and continued in bright phase. We could obtain one of the longest duration light curves for PKS0716+714 and 3C66A in near IR from October 2003 to March 2005. The source was consistently in bright phase during the monitoring. On the long term brightened base level, variations on short time scales are superposed. There is an increase of more than 1.0 mag between December 2003 and January 2005 in both the sources, which is due to the December 2003/March 2004 outbursts. Several enhancement of the order of 0.3 - 0.5 mag are also noticed over couple of days time scale without any clear periodicity. From light travel time arguments, emission regions appear to be of the order of solar system.

(K.S. Baliyan, U.C. Joshi and S.Ganesh)

Radio Observations of Rapid Acceleration in a Slow Filament Eruption / Fast Coronal Mass Ejection Event

A filament eruption/coronal mass ejection (CME) event associated with a flare of GOES class M2.8 that occurred on November 17, 2001 was studied in detail. This event was observed by the Nobeyama Radio Heliograph (NoRH) at 17 and 34 GHz. NoRH observed the filament during its eruption both as a dark feature against the solar disk and a bright feature above the solar limb. The high cadence of the radio data allowed one to follow the motion of the filament at high time resolution to a height of more than half a solar radius. The filament eruption showed a very gradual onset and then a rapid acceleration phase coincident with the launch of a fast halo CME. Soft X-ray and extreme-ultraviolet (EUV) images show heating in a long loop underneath the filament prior to the flare. The NoRH height-time plot of the filament shows a roughly constant gradual acceleration for 1 hr, followed by a very abrupt acceleration coincident with the impulsive phase of the associated flare, and then a phase of constant velocity or much slower acceleration. This pattern is identical to that recently found to occur in the motion of flare-associated CMEs, which also show a sharp acceleration phase closely tied to the impulsive phase of the flare. When the rapid acceleration occurs in this event, the flare site and the filament are separated by ~0.5 $R_{\odot}$, making it unlikely that the disturbance propagated from one location to the other. Models in which a disruption of the large-scale coronal magnetic field simultaneously permits the acceleration of the filament and the flare energy release seem to be a better explanation for this event.

(P. Janardhan, Mukul Kundu, S. White, V. I. Garaimov, Prasad Subramanian, S. Ananthakrishnan and P.K. Manoharan)

Combining Visibilities from the Giant Meterwave Radio Telescope and the Nancay Radio Heliograph to Produce High Dynamic Range Snapshot Images of the Solar Corona at 327 MHz

Imaging complex, rapidly varying radio sources in the solar corona is not easy because one needs to obtain images spanning durations as short as a few seconds. The uv-coverage for short duration exposures is usually quite poor, and this affects the ability to image complex sources reliably. Furthermore, deconvolution algorithms like the commonly used *CLEAN* procedure often perform poorly on sources that exhibit structures on a variety of scales, for instance, studies of extended thermal emission in the corona, coronal mass ejections (CMEs) that frequently occur together with narrow, bright bursts and flare continua. All of these phenomena require imaging with a large field of view, high spatial resolution and dynamic range.

An ongoing program of combining data from the *GMRT* and *NRH* in order to make composite meter wave-

length images of the sun is continuing. The aim is to combine the short baseline data from the *NRH* with long baseline data from the *GMRT* in order to obtain meter wavelength images of unprecedented resolution and fidelity. A number of combined observations between the GMRT and NRH have been carried out and high dynamic range images have been obtained.

(P. Janardhan, Prasad Subramanian, S. Ananthakrishnan, C. Mercier, Alain Kerdraon and Monique Pick)

Geo-effectiveness of Solar Wind Extremes

The density and speed of the solar wind flow is highly variable both in time and space leading to the common occurrence of the plasma irregularities in the medium around planets. The geo-environment is affected by both the high and low extremes of the solar wind in a variety of ways. An interesting observation and analysis of a solar wind disappearance event which represents one of the extreme conditions of the solar wind have been made. In that event it was found that the disappearance happened due to the passage of Earth through void (low density, slow solar wind region). After the passage of the void, there was a mild geomagnetic storm. Interestingly this storm was not associated with the southward turning of the z-component of the interplanetary magnetic field, instead, it was associated with fluctuations in Bz in the vicinity of Earth. Yet another extreme of solar wind was observed during October- November, 2003. Using ACE data during the above period, detailed investigation of the geo-effectiveness of this solar wind extreme has been carried out.

The geomagnetic index Kp is low for low +ve Bz; Kp is mostly low for -ve Bz and Kp is high or very high for high +ve Bz which is in contrast with a general belief that a large geomagnetic storm is usually associated with the -ve Bz. It was found that geomagnetic conditions were mostly controlled by the RAM and the magnetic pressure of the solar wind. A ten fold increase in solar wind pressure was found to enhance Kp by ~3.

(Hari Om Vats)

Correlation Analysis of Shadow Bands

The observing geometry of the total solar eclipse of November 23, 2003 over Indian Antarctic Station "Maitri" was a rare opportunity for the observations of shadow-bands. The shadow bands were observed for 4 minutes before the totality and 7 minutes immediately after the totality. These are the longest duration of shadow-bands clearly recorded ever. The recording was done in colour by digital video camera and thus provided an opportunity to investigate shadow bands in R, G, and B bands. The cross-correlograms along the direction of motion showed a gradual fall with the increase of spatial lag along x-direction on the screen (**Fig.1.5**). On the other hand cross correlations showed a sudden decrease in the transverse direction (i.e. y-axis on the screen). This indicates that the motion of the shadow bands formed during this event was mostly horizontal and vertical motion was almost absent.

(Hari Om Vats, S. M Bhandari and S. P. Bagare)

Space Weather and Solar Flares

X-flares, the most powerful kind of solar explosions, have severe effects on radio and satellite communications. The effects on communication are due to excessive ionization in the lower part of ionosphere and the

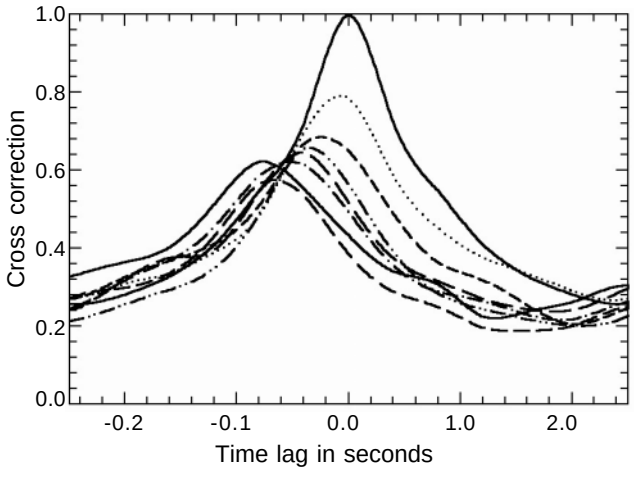


Fig. 1.5 : Cross correlation of the shadow bands at several spacing along x-axis

plasma turbulence. The duration of radio black-outs due to excess ionization in the lower atmosphere increases with the duration of solar flares. Efforts are on to make an empirical formula for excess ionization and their duration with the intensity and duration of the solar X-ray flares.

(Hari Om Vats, Som Kumar Sharma, H. S. S. Sinha and H. Chandra)

Transit of Venus: A Rare Spectacle

The rare solar transit of Venus was observed from Gurushikhar, Mt.Abu on June 8, 2004 using the 20 cm Robotic telescope. The telescope was specially equipped with a solar filter and a 795 x 596 pixel CCD operating at the video rate of 25 frames per second. In addition, a special filter with a narrow bandwidth of 15 A was also used to isolate the Hydrogen alpha emission from the Sun at 6563 A. Exact time information was available for each frame from a GPS synchronised clock. Selected video images were digitised and sent to the PRL computer centre every few minutes over a hot line so that nearly real time display of the transit could be seen at Ahmedabad. At Gurushikhar early morning clouds cleared up by about 9 A.M. The I and II contacts were well recorded. The III and IV contacts were, however, clouded out.

(T. Chandrasekhar and P.K. Kikani)

Predicting the Occurrence of Super-storms

A comparative study of five super-storms (D_{ST} < -300 nT) of the current solar cycle to identify solar and interplanetary variables that influence the magnitude of resulting geomagnetic storms has been done. Amongst solar variables, the initial speed of a coronal mass ejection (CME) is considered the most reliable predictor of the strength of the associated geomagnetic storm because fast mass ejections are responsible for building up the ram pressure at the earth's magnetosphere. However, although most of the super-storms studied were associated with high speed CMEs, the D_{ST} index of the resulting geomagnetic storms varied between - 300 to - 472 nT. The most intense storm of November 20, 2003 (D_{ST} ~ - 472 nT) had its source in a comparatively smaller active region and was associated with a relatively weaker, M-class flare while all other super-storms had their origins in large active regions and were associated with strong X-class flares. However, this superstorm did not show any associated extraordinary solar and interplanetary characteristics. The study also reveals the challenge in reliable prediction of the magnitude of geomagnetic storm from solar and interplanetary variables.

(Nandita Srivastava)

A Regression Model for Predicting the Occurrence of Intense Geomagnetic Storms

A regression model for predicting the occurrence of intense/super-intense geomagnetic storms is implemented. A binary dependent variable indicating the occurrence of intense/super-intense geomagnetic storms is regressed against a series of independent model variables that define a number of solar and interplanetary properties of geo-effective CMEs. The model parameters (regression coefficients) are estimated from a training data-set extracted from a data-set of 64 geo-effective CMEs observed during 1996-2002. The trained model is validated by predicting the occurrence of geomagnetic storms from a validation data-set, also extracted from the same data-set of 64 geo-effective CMEs recorded during 1996-2002, but not used for training the model. The model predicts 78% of the geomagnetic storms from the validation data-set. In addition, the model predicts 85% of the geomagnetic storms from the training data-set. These results indicate that logistic regression models can be effectively used for predicting the occurrence of intense geomagnetic storms from a set of solar and interplanetary factors. The results indicate that the model is highly successful in predicting the occurrence of intense geomagnetic storms, although it is only moderately successful in predicting super-intense storms. The results also indicate that interplanetary variables are better predictors of the occurrence of geomagnetic storms, while the solar variables, in general, contribute relatively less in the prediction.

(Nandita Srivastava)

Propagation Characteristics of Geo-Effective CMEs

The plane-of-sky speeds of several halo coronal mass ejections observed by LASCO aboard SoHO during 1996-2003 which produced strong geomagnetic storms (D_{ST} < - 100 nT) have been measured. The radial propagation profiles of these CMEs have been inferred from the measured plane-of-sky speeds. We also investigate if the propagation profiles of these geo-effective CMEs are of blast wave nature. A comparison of observed propagation profiles with the Sedov-type power-law blast waves show that the profiles are distinctly different for the geo-effective CMEs associated with the flares than those associated with eruptive prominences. This difference in behaviour of propagation profiles may provide a clue to the initial trigger mechanism of geo-effective halo CMEs and their nature of propagation in the ambient solar wind.

(Nandita Srivastava)

Magnetic and Velocity Field Evolution in NOAA 10486 and the Signatures of the 4B/X17 Superflare

Extensive efforts have been made in the past decades to identify the conditions and magnetic topology leading to the onset of flares and CMEs. Moderate flares may occur where newly emerged flux gets cancelled with opposite polarity, presumably by reconnection and can trigger the release of magnetic energy stored in

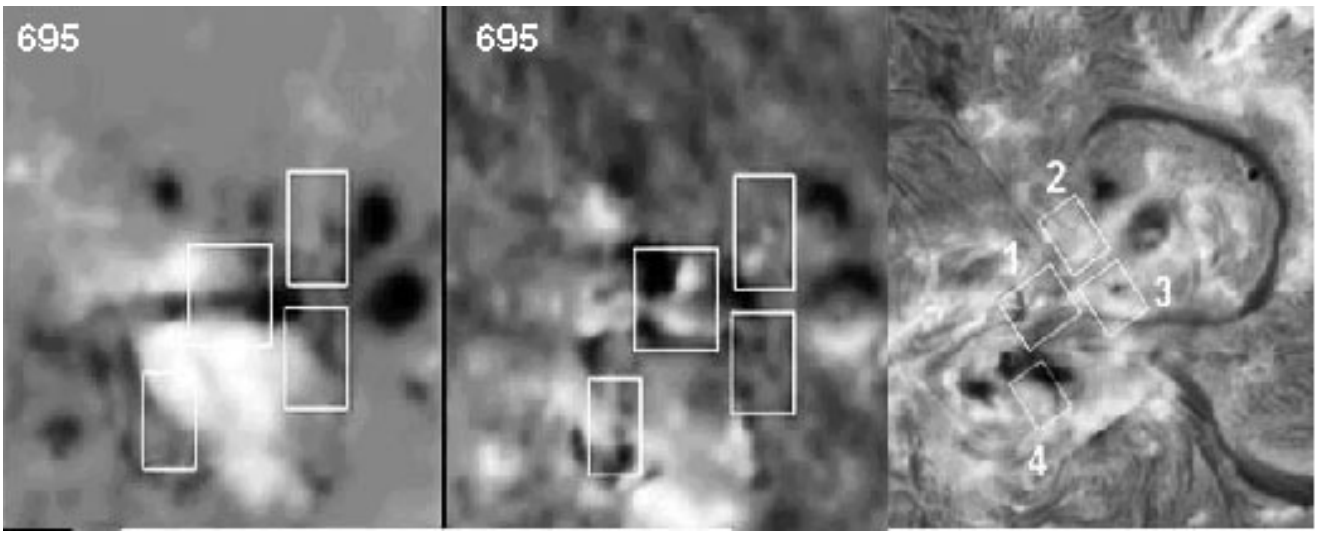


Fig. 2.1 : GONG+ line-of-sight magnetogram, corresponding Dopplergram and USO H-alpha filtergram of NOAA 10486 on October 28, 2003, showing the areas-of-interest (marked by boxes) where new fluxes emerged and changes in velocity flows were noticed.

much larger volume. We have used the GONG+ photospheric velocity, and magnetic field observations along with the chromospheric H-alpha observation carried out from USO for NOAA 10486 during October 26-29, 2003 to study its flares. This superactive region accounted for most of the extremely energetic flares which occurred in this period of anomalous solar activity. Using movies made from our observations, we identify the sites of magnetic flux emergence, and the line-of-sight velocity flows in the active region. Upward (and downward) flows developed near the filament, alongwith new magnetic flux emergence (**Fig. 2.1**). This could have led to destabilize the large filament observed to delineate the narrow channel of opposite polarity. The MSFC vector-magnetograms showed existence of strong magnetic gradient and shear along the filament, which persisted even after the X17.2 flare of October 28, 2003. The magnetic free energy was found adequate to account for the

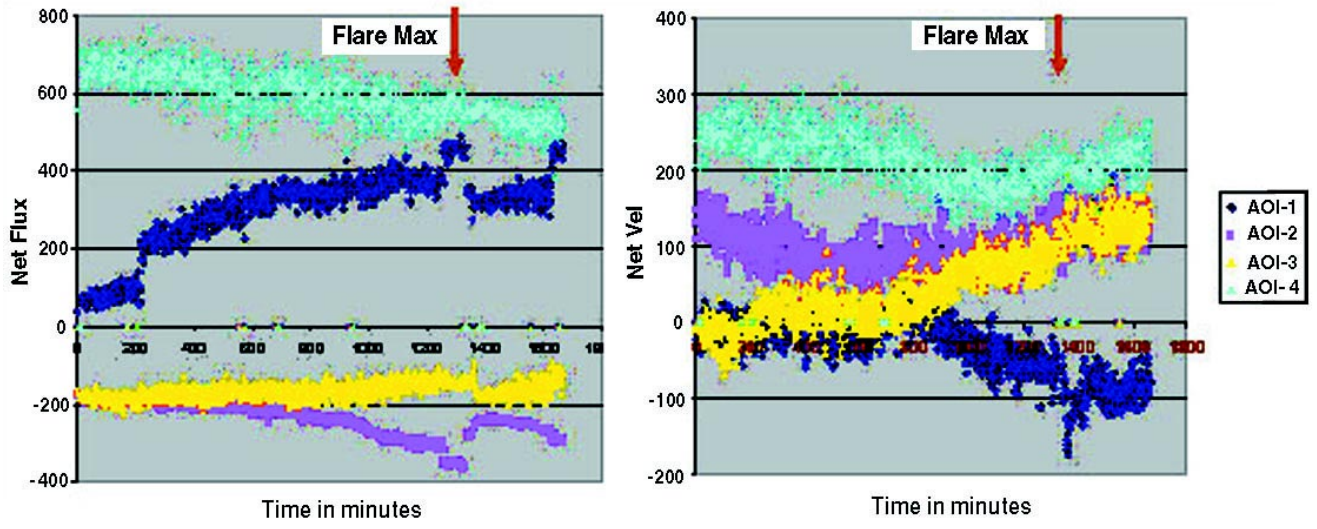


Fig. 2.2 Temporal variations in net magnetic fluxes (left panel) and line-of-sight velocity flows (right panel) showing both evolutionary and flare-related changes.

subsequent white light flare of October 29, 2003. Large flux motions near the flare site in NOAA10486 were also observed before the flare onset. Using the GONG+ Doppler (line-of-sight velocity) and magnetic data-cubes taken at a cadence of 1 minute, we have evaluated the net magnetic and velocity flux during 2003 October 27/ 12:26-October 28/16:09 UT for some areas of interest. Time profiles for these tracked regions are given in **Fig. 2.2**. Both evolutionary and flare-associated changes have been inferred from these profiles.

(Ashok Ambastha)

Umbral Brightness Evolution over Solar Cycle 23

A variation in umbral core brightness with solar cycle have been reported. From the analysis of 20 sunspots which cover solar cycle 20 and 21, it was found that the umbral core intensity increases from early to the late phase of the cycle. This topic is studied by analyzing a large number of sunspots observed by SoHO/ MDI instrument for the period between June 1996 to March 2004. The data set cover the early through the middle phase of solar cycle 23. We utilized full disk continuum images observed with the above instrument for this purpose. The advantage of this data set is its homogeneity, with no seeing fluctuations. A careful stray light correction is carried out before obtaining the umbral core intensities. Data for more than 200 sunspots, with umbral radius greater than 5 arc-secs are included in the analysis. The initial results show no considerable variation in umbral core, mean and mean penumbral intensities with solar cycle.

(Shibu K. Mathew, Martinez Valentin Pillet, Sami K. Solanki & Natalie Krivova)

Meridional and Zonal Velocities Underneath the Super-active Regions Observed during October 2003

Solar flares are amongst the most energetic phenomena observed on the solar surface with catastrophic magnetic energy release over a localized region on solar disk. These are usually associated with prominent chromospheric and coronal signatures, and in exceptional events even at the photospheric level. It would be interesting to test whether velocity flows in the sub-photospheric levels are different for flaring as compared to non-flaring regions. The large active regions NOAA 10484, 10488 and the superactive region NOAA 10486 observed during October 2003 provided an opportunity to carry out such a study. Using ring diagram analysis, it is possible to obtain velocity along the horizontal directions, apart from the amplitudes. The fitted velocities can be inverted to calculate the zonal and meridional components of velocity as a function of depth. Both Regularized Least Squares (RLS) and Optimally Localised Averages (OLA) techniques have been used for inversion. It is found that in the flare productive NOAA10486, meridional velocity has a steep gradient below a depth of 5 megameter (Mm). On the other hand, the gradient is much less in NOAA 10484. Also, there is no meridional velocity gradient in regions R21, R22 of NOAA 10488 as the active region had not yet emerged, however, the gradient developed subsequently as the active region formed and the flares took place. Apart from the meridional component the subsurface shear layer normally present in the zonal component seems to have disappeared in flaring regions. We found similar behaviour for some other major active regions which produced large flares, for example, NOAA 9026 and 9393. Infact, for NOAA 9026, meridional velocity showed steep gradient, which disappeared after the flares. Furthermore, sound speed difference between an active and quiet region showed that sound speed is lower in the active region just below the surface, but at depths exceeding 7 Mm the trend reverses.

(A. Ambastha, H.M. Antia, Sarbani Basu and R. Bogart)

Global P-mode Power and its Relationship with Disk-integrated Solar Flare Activity and CMEs

The power of solar p-modes has been found to vary on temporal scales of days to several weeks. The observational variations can be explained by models based on the assumption that the modes are stochastically excited by turbulent convection. However, some observational features of sun-as-a-star, which use low-l p-mode data, indicate about excess of excitation events at large powers. This is not explained by stochastically

forced, damped oscillator models. This suggests that energetic solar events, such as, flares may have some correlation with the p-mode power. In order to investigate this possibility, we have compared the temporal variation of power in low-l modes, using GONG+ data with solar disk integrated flare-index for the period of 1995-2001 covering the ascending phase of the current cycle. We have also obtained CME-counts for the period 1996-2003 from the LASCO list. We find that there is no obvious correlation of mean power of low-l modes with disk-integrated flare index or CME-counts. The mean level of running mean power is found to vary; decreasing from solar minimum to ascending phase of solar cycle 23. This is as expected because of increasing level of magnetic fields. CME-counts are found to be reasonably well-correlated to the disk-integrated flare index FI, and show similar mild-anticorrelation with mode power as does the FI. Also, power distribution of low-l modes was found to follow the theoretical χ^2 -type distribution with no significant features seen at large-power. This supports the generally accepted mechanism of stochastic excitation of p-modes by turbulence. The power spectrum of the running mean power for radial modes of low-l shows no prominent periodicities. A mild indication of 62, 116, and 250 day periods may be indicative of some quasi-periodicities for individual radial modes, which disappear when sum of powers over these modes is considered.

(A. Ambastha and H.M. Antia)

Enhanced P-mode Absorption Seen outside the Umbral -penumbral Boundary of a Sunspot

The p-mode absorption in a sunspot has been studied using the Solar and Heliospheric Observatory/ Michelson Doppler Imager (SoHO/MDI) high resolution images. By computing the Doppler power from three and half hours of data set, we look in the absorption of p-mode power in the sunspot in a small frequency band which include 3.3 mHz (5 min.), to investigate the location dependence of absorption within the sunspot. From the analysis we found an enhanced absorption just outside the umbral-penumbral boundary. Relating the absorption with the line-of-sight magnetic field strength, we found that, even though the field increases towards the umbral core the maximum absorption is already reached near the umbral-penumbral boundary and decreases towards the center of the umbra. We propose a possible explanation by taking magnetic field orientation into consideration. The line-of-sight magnetic field give information more on the vertical field, especially when the sunspot is near the disk center, and give little information on the radial field. In order to explain the enhanced absorption near the umbral-penumbral boundary, we consider the standard magnetic field structure of a sunspot. The radial field in a sunspot reaches a maximum near or outside the umbral penumbral boundary. Looking into the location of enhanced absorption and standard magnetic field structure of the sunspot, we suggest that, the strength of the radial field component is more important for the absorption than that of the vertical field. In other words, more inclined field in a sunspot might be absorbing more power than the more vertical field.

(Shibu K. Mathew)

Effect of Flare on Acoustic Oscillations

Detection of variations of magnetic fields associated with flares and CMEs is an important problem in solar physics. Fast Fourier Transform (FFT) is not suitable for studying the transient and quasi-periodic oscillations. Wavelet analysis is suitable in those conditions, since this provides localized frequency and temporal information of any fluctuations. GONG+ Dopplergrams have been used to study the the effect of October 29, 2003 X10 flare and November 02, 2003 X8.3 flare in active region NOAA 10486, on acoustic oscillations using wavelet analysis technique. The preliminary results showed reduced power in 5-minute band and enhanced power in higher frequency band in the active region as compared to the quiet Sun in the absence of flare. Flare induced oscillations are observed which are localized at some portions, mostly in the hard X-ray producing regions. In addition, there is excitation of high as well as low frequency oscillations during these large X-class flares. It is not clear whether the observed flare induced oscillations are real or an artifact of flare (broadening of line profile) or due to the high energetic electrons bom-

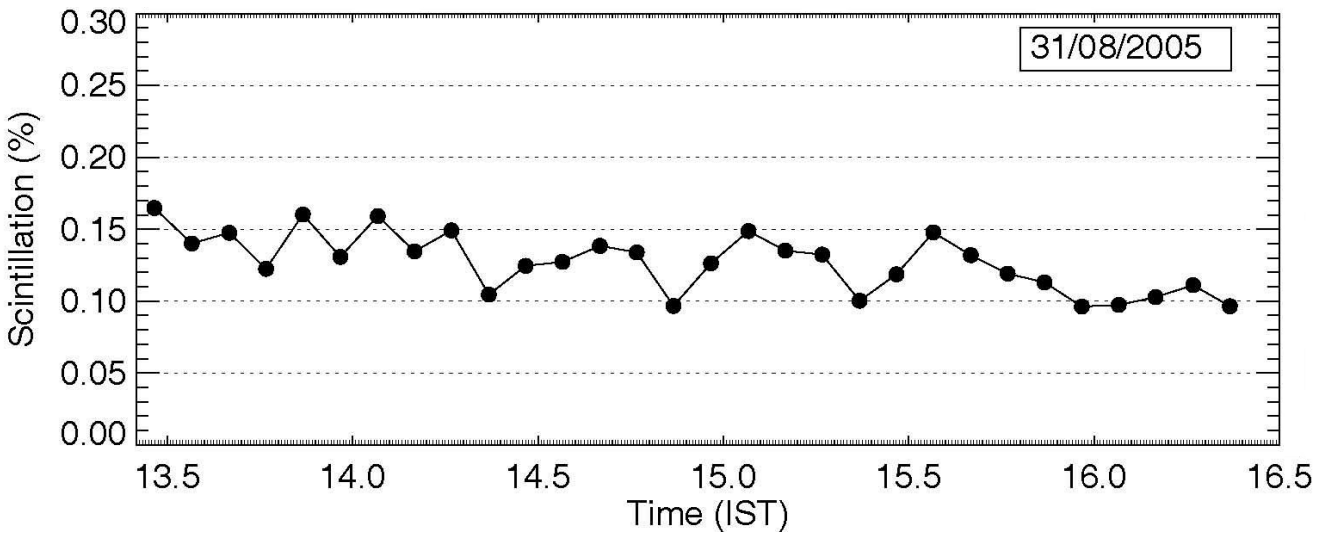


Fig. 2.3 Six minute average of scintillation taken on March 31, 2005 at the Udaipur Lake site

barding the foot points of magnetic field lines. These observations may give a new clue to the mechanism of flare production in active regions.

(B. Ravindra and Brajesh Kumar)

Scintillometer Development for MAST site Characterization

There is a correlation between the amount of scintillation of the solar irradiance and image motion. Scintillation measurement is a good parameter to compare different sites in terms of image quality. We developed a scintillometer which has been deployed at Udaipur lake site and have started obtaining data (**Fig. 2.3**) from this instrument. The scintillometer data is being compared with the measurements of the Fried's parameter r_0 obtained from the high resolution Hα observations using the USO-spar telescope. Since the instrument is mounted on the spar telescope, the comparison should give a correlation between the percentage scintillation and r_0 measurements. The initial observations showed a very low correlation between the two.

(Shibu K. Mathew, S. K. Gupta and P. Venkatakrishnan)

Preliminary Results on the Calibration and Control of an Adaptive Optics System

In an adaptive optics system, the image stabilization is achieved by using tip-tilt and deformable mirrors. These mirrors are actuator driven devices. Hence, there is a need to know the response of these actuators with respect to the applied voltages. This process is known as calibration of any actuator driven system. The calibration helps in determining the overall gain of the system. The gain of the tip-tilt system is found to be 0.03 Volts/pixel in 'channel 0' and 0.017 Volts/pixel in 'channel 1' for the current setup. A Proportional (P), Integral (I) and Differential (D) type control to tune the tip-tilt control system is being used. However, for the current setup, only a PI controller is being used. The value of 'I' estimated from closed loop tuning method seems to be high and hence we replace it with a very small value of the order of 0.005. We have obtained the following results in our experiments related to PID (D= 0 in our case) using Zeigler Nichols method both in closed and open loop tuning methods. Closed-Loop: (Channel 0) [P = 25.65, I = 2.19] and for Open loop: (Channel 0) [P = 22.7, I = 0.024] & (Channel 1) [P = 9.5, I = 0.021].

Presently, these values (obtained from open loop method) have been used in closed loop operation. However, it was found that the system is stable for a range of P and I values given as: (Channel 0): [P = 18-30 & I = 0.02-0.05] ; (Channel 1): [P = 8-15 & I = 0.02-0.05].

(Brajesh Kumar, R. Sridharan, A. Raja Bayanna and P. Venkatakrishnan)

Phase Diversity Technique for High Resolution Solar Imaging

The diffraction limited performance of the ground based telescope is affected by the phase aberrations induced by the atmosphere. Real time techniques such as adaptive optics (AO) and post processing techniques such as Speckle imaging and phase diversity (PD) technique are very promising to estimate the aberrations. Based on the advantages of PD technique over AO and Speckle imaging, PD technique was used in achieving high resolution in an incoherent imaging system. PD technique estimates the aberrations from image data obtained by the imaging system. For estimating the phase errors it needs two images, one in focus and the other out-of focus. The focused and de-focused images following Kolmogorov turbulence theory were simulated and analyzed using the PD technique. The object is restored by correcting 12 Zernike terms (4 -15) of the turbulence. **Fig. 2.4** shows the preliminary results obtained by using the code for PD technique being developed at USO. The simulations indicate that the code can restore original object faithfully under good seeing conditions (r_o > 9 cm). Artifacts arise under bad seeing conditions (r_o = 5 cm and 3 cm). Nevertheless, the object could be retrieved by increasing the number of terms corrected, or by filtering the restored object with appropriate filters. Beyond certain spatial frequencies, filtering leads to loss of information.

(A. Raja Bayanna, R. Sridharan and P. Venkatakrishnan)

Imaging with Insolated Mirrors

Modern solar telescope designs are different from the conventional concept of vacuum telescopes. These new designs are “open” telescopes which try to minimize the temperature difference between various parts of the telescope and the ambient air. In this work, we address a few issues related to the thermal response and image quality of such insolated mirrors. We estimate the distortion produced by thermal and material inhomogeneities and present limiting values of allowable temperature differences and percentage change of expansion coefficients for different sizes of the aper-

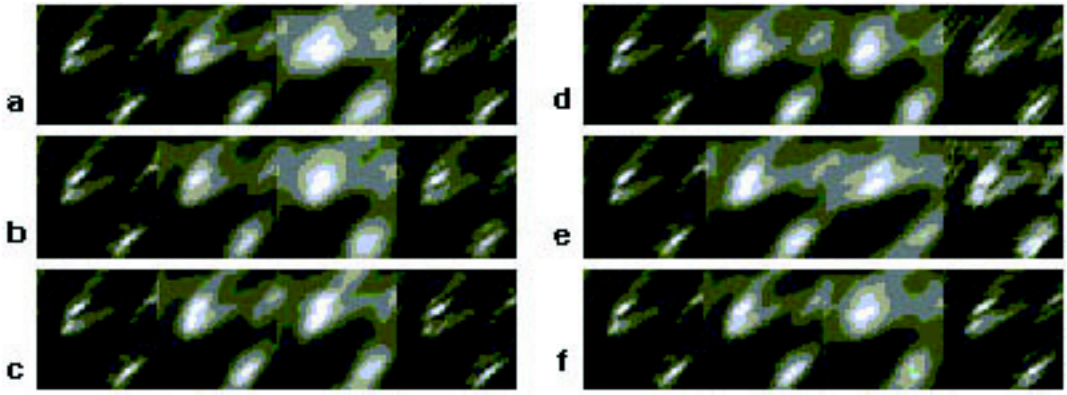


Fig. 2.4 Performance of the PD technique under seeing conditions of r_0 = 5 cm. Here the RMS error of the instantaneous wavefront varies from 0.2 λ to 1.15 λ. In all the images from a to f, the first column represents the reference image for simulation obtained from New Swedish Solar Telescope, The second column is the focused image through the turbulence, the third column is the defocused image through the turbulence. The restored object using PD technique is shown in the fourth column.

ture, for typical materials under best possible seeing conditions. We predict the evolution of surface temperature of an insolated mirror using a simplified theoretical approach and show that it is compatible with the experimental values to a large extent. The results indicate the possibility of avoiding active cooling of the mirror surfaces, at least for primary mirrors with apertures less than or equal to 50 cm.

(P. Venkatakrishnan, R. Sridharan, and S. K. Gupta)

Solar Vector Magnetograph (Phase –I)

We present the status of the Solar Vector Magnetograph Phase -I (SVM-I) currently being developed at USO. SVM-I is an instrument for determining magnetic field vector in the solar atmosphere by measuring Zeeman induced polarization across the spectral line. The instrument is currently in a preliminary development stage, with all components under evaluation process. The integration of components is being done. The integrated performance of the system on a tracking mount (**title cover**) and its control software is being evaluated. Some, test observations of sunspots has been carried out (**Fig. 2.5**).

(Sanjay Gosain and P. Venkatakrishnan)

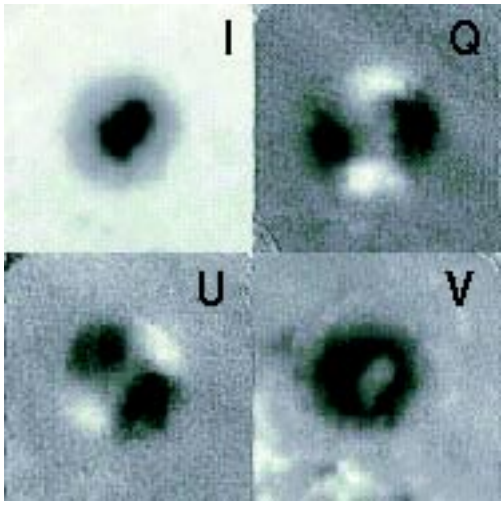


Fig. 2.5 : Maps of I, Q, U, V, Stokes Parameters of a sunspot.

H-alpha Observation of Venus Transit of June 8, 2004

The Venus transit of 2004 provided a rare opportunity for its multi-wavelength observation, using ground-based and space-borne instruments. The event lasting over 6 hours was recorded, for the first time, in Hα 6563A from USO's island observing station and about 4000 digital images were obtained. White light full disk observation in Ni I6767.7A wavelength was also made from USO at a cadence of 1 minute using the GONG instrument. For a comparison of the Hα observations, we have used the images obtained from the Transition Region and Coronal Explorer (TRACE) satellite in white light 5000A, UV 1600A of the ionized carbon, and EUV 171A of the ionized iron Fe XV. The formation heights of these lines range from the temperature minimum region in the photosphere to the corona. Based on these ground-based and space-borne observations, we derive the following conclusions: The contact timings of Venus with the solar limb differ when observed in different wavelengths, i.e., the Hα 6563A and the GONG 6767.7A, even from the same geographical location. A large comparable scattered light level is found for both the ground-based Hα and the 171A TRACE observations. However, for the TRACE white light and 1600A observations, this level was found to be significantly lower. The angular size of Venus was found to be around 59 arc-sec, having little variation with wavelength. The black drop effect is clearly visible in the TRACE white light, and the USO Hα images, while it is less conspicuous in the TRACE UV1600A, and is absent in the EUV 171A wavelength (**Fig. 2.6**). No ''aureole'' around the planetary disk of Venus was noticeable in our Hα observations during the ingress or egress phases of the transit. The black drop effect observed in the white light and Hα could be attributed to the solar limb darkening, atmospheric seeing and the instrumental effect. However, the fact that this is also visible in TRACE white light images, and to a lesser extent in 1600A images (where no atmospheric seeing effect is present), but not in 171A images (where limb brightening is present), suggests that solar limb darkening is an important factor in causing the black-drop effect in both the ground-based and space-borne observations.

(Ashok Ambastha, B. Ravindra and Sanjay Gosain)

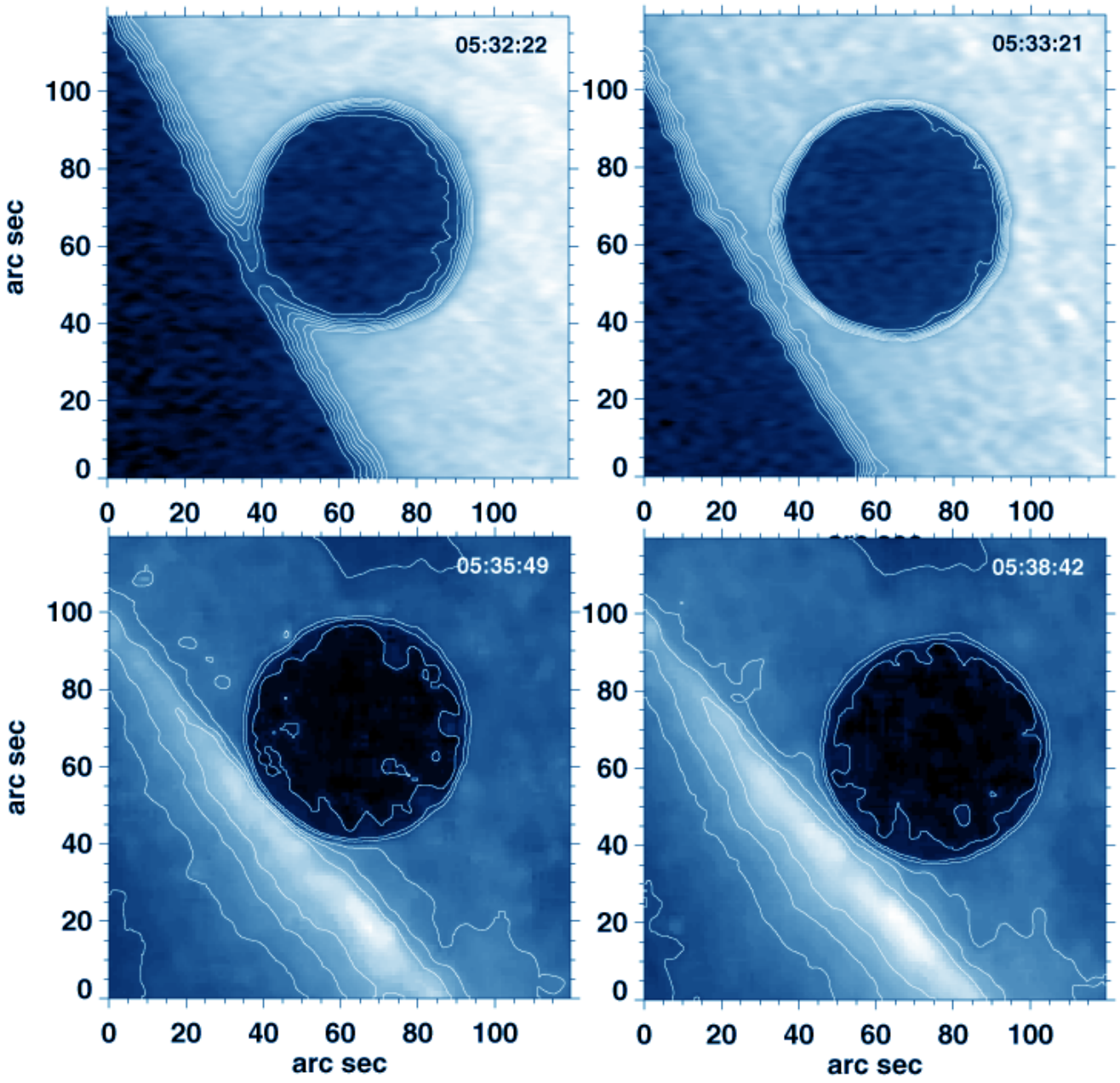


Fig. 2.6 : The isophotal contour maps overlaid upon the corresponding images to identify the black-drop effect in Venus transit event of June 8, 2004. The top panel shows the USO's chromospheric images in H? 6563 Å, while the bottom panel shows coronal images taken by TRACE satellite in the Extreme Ultra-violet (EUV) wavelength

Submillimeter Data Analysis

The process of star formation is linked to the chemistry, composition, structure and thermal balance within molecular clouds. The balance of this process determines the composition of the gas and thus the abundances of the atoms and molecules available to cool interstellar clouds. This is of vital importance to the star formation process because molecular cloud cores can only undergo gravitational collapse in so far as gravitational potential energy can be radiated away. Consequently cores possessing a high abundance of species with low lying ($E/k \leq 30K$) easily excited transitions, such as CI, H_2O and CO, will cool more effectively and facilitate collapse. Submillimeter-wave emission line techniques permit large scale mapping of the environments of star formation through CO and its isotopes. Observations of ^{12}CO (2-1) provide a picture of the thin extended gas and the ^{12}CO (3-2) data show the distribution of the dense and warm molecular gas. The combination of observations of these lines thus allows to distinguish between extended, quiescent gas, dense cold parts, and warm regions, influenced by star formation. As part of an ongoing study, the data obtained by the submillimeter survey of L134N (Lynds 134 N) source including ^{12}CO (1-0), ^{13}CO (3-2) lines observed with help of NRAO-12m and CSO-10m in collaboration with the LERMA group of Paris Observatory, France have been reduced. These spectral data have been reduced using Continuum and Line Analysis Single dish Software (CLASS).

L134N (also known as L 183) is a starless cold cloud and its temperature is nearly about 8 to 12K. It is located high above the galactic plane with a galactic latitude of 36^o, and it is isolated and uncluttered by other emission along the line of sight. It is oxygen rich cloud (due to the presence of CO, SO, SO_2,CH_3OH) and known to contain high amounts of oxygen bearing molecules.

Raw data contains 78 spectra, taken 2 by2 of ^{12}CO line and of 98 observations of ^{13}CO (3-2) data from cold cloud L134N where ^{12}CO (1-0) data was done in the frequency switched mode which is similar to the beam switched observations in that the signal and reference spectra are accumulated simultaneously and synchronously. Frequency switched observations differ in that the center frequency of the observation that is toggled between two values. Frequency/Velocity calibration has been taken care for the observed data and various factors such as Doppler broadening associated with the spectral broadening are considered in this data reduction. The baseline subtraction for all the spectra was also carried out. Analyzed results show that most of the observations fit well with double Gaussian and such multiple component nature could be due to possible self absorption features. ^{12}CO (1-0) line is a very optically thick line and the molecule is largely depleted inside the cloud (above Av ~ 20 mag), which leads to the estimation of absolute abundance which is a difficult task.

Based on the LTE analysis, we infer that the excitation temperature was rather uniform over the cloud within 1 K. The column density estimates were based on the average value of 8.4 K. In cloud cores the CO molecules freeze out on to the surfaces of the cold dust grains. (Direct evidence of this process is available from the observations of the molecular ice features). This may alter the properties of the dust grains and may explain some of the color of L134N. In the center of L134N the visual extinction exceeds 10m and CO depletion of similar order has been detected in other clouds. Further analysis is underway.

(Hemant Dave, Satheesh Thampi, Bhavik Kodrani, Ashish Dubey, Vinay Kumar and Ravindra Pratap Singh)

SMM Technology Development

LO Development

In the continuation of development of compact SMM / FIR laser source for airborne payloads, we are studying the various configurations of laser cavities with innovative structures like slotted waveguides. In recent work, we have applied the modified theory of microwave waveguides to the oversize dielectric waveguides with slots on top surface, for simulating the output intensity profile in the elevation plane. We considered 700 GHz as the operating frequency for standard WR-10 waveguide. Result shows that random spacing between slots provides the lowest side lobe level. In comparison to all the other cases, the side lobe appears very far from the main lobe in this case. Thus, with this geometry of slot con-

figuration, much more power can be extracted and coupled to the detector for further processing.

(Hemant Dave and Ashish Dubey)

High Resolution Chirp Transform Spectrometer Development

The high resolution state-of-the-art Chirp Transform Spectrometer (CTS) has been designed with ability to process 200 MHz IF bandwidth with centre frequency 1250 MHz and frequency resolution 40 kHz. It is based on the chirp transformation technique used to get frequency spectrum of unknown CW signal. Phase spectrum of the signal may not be required in astronomical observations and can be omitted. Simulations have verified performance of chirp processor. Initial design parameters of state-of-the-art Surface Acoustic Wave (SAW) devices for CTS have been generated and fabrication of first cut of device is completed. It is under testing like magnitude and delay measurement, profile measurement of grooves etc. These chirp filters are Reflective Array Compressor (RAC) type SAW filters providing very high time bandwidth product. The negative chirp signal required for the spectrometer is digitally generated using programmable chirp synthesizer and up converted by frequency multipliers to the required level. The testing of subsystems of CTS has been started. The simulation results of groove response of RAC device with different conditions of width are depicted in the plots of **Fig. 3.1**. The change in magnitude in the pass band is about 4 dB for both conditions. The simulation result with constant length showed a change of about 17 dB in magnitude in the pass band, which is depicted in **Fig. 3.2**. The change in shape of magnitude response is not observed when depth of grooves is taken larger except that it is shifted upward. The photo-resist image of the SAW RAC grooves is shown in **Fig. 3.3**.

(Hemant Dave, Jayesh Pabari, N. M. Vadher, A. B. Shah, Ashish Dubey, Vishal Shah, V. D. Patel and S. L. Kayasth)

Soft X-ray Line Emission from Solar X-ray Spectrometer (SOXS) Observations

The SOXS mission onboard GSAT-2 Indian spacecraft was launched successfully by GSLV-D2 rocket on May 8, 2003 to study the energy release and particle

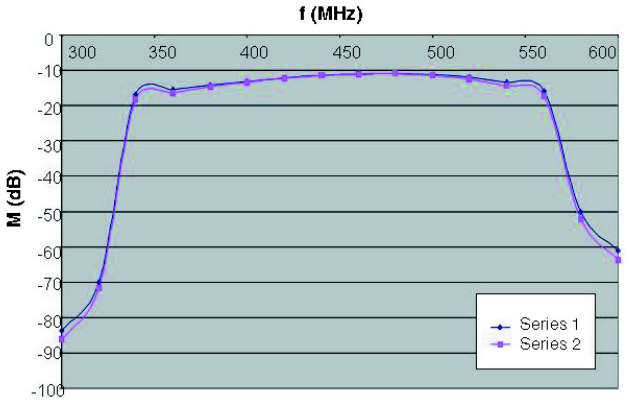


Fig. 3.1 : RAC groove response (Comparison of constant width and varying width; depth = 1000 Angstrom)

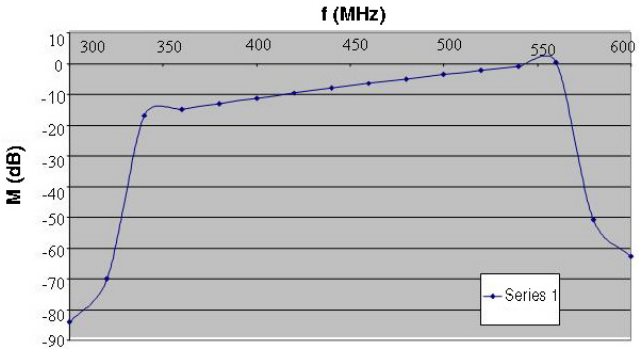


Fig. 3.2 : RAC groove response (Constant length and varying width, depth = 1000 Angstrom)

Fig. 3.3 : Photo-resist image of exposed grooves having SPD data with 100X. Step size is 0.01 microns

acceleration in solar flares. The SOXS is composed of two independent payloads viz. SOXS Low Energy Detector (SLD) payload, and SOXS High Energy Detector (SHD) payload. The SLD payload employs the state-of-the-art solid state detectors viz. Si PIN and Cadmium-Zinc-Telluride (CZT) devices that operate at near room temperature. The dynamic energy range of Si PIN and CZT detectors are 4-25 and 4-56 keV respectively. The Si PIN provides sub-keV energy resolution while CZT reveals ~2 keV throughout the dynamic range.

Fe and Fe/Ni line features have been detected during solar flares. A detailed analysis of a few flares showing these lines unambiguously have been carried out. The line parameters such as peak energy, temperature, emission measure, equivalent width for these lines have been measured and compared with those predicted theoretically. It was found that Fe/Ni line appears when the temperature of the flare plasma exceeds 15 MK in contrast to Fe line features which appear around 10 MK. In **Fig. 3.4** the photon spectrum revealed by Si detector at the peak time of the flare observed on July 14, 2004, shows Fe and Fe/Ni line features at 6.7 and 8 keV respectively. Study of line evolution as a function of temperature reveals that Fe/Ni line is very sensitive to temperature in the plasma.

(Rajmal Jain, Hemant Dave, Vishal Joshi, K. J. Shah and M. R. Deshpande)

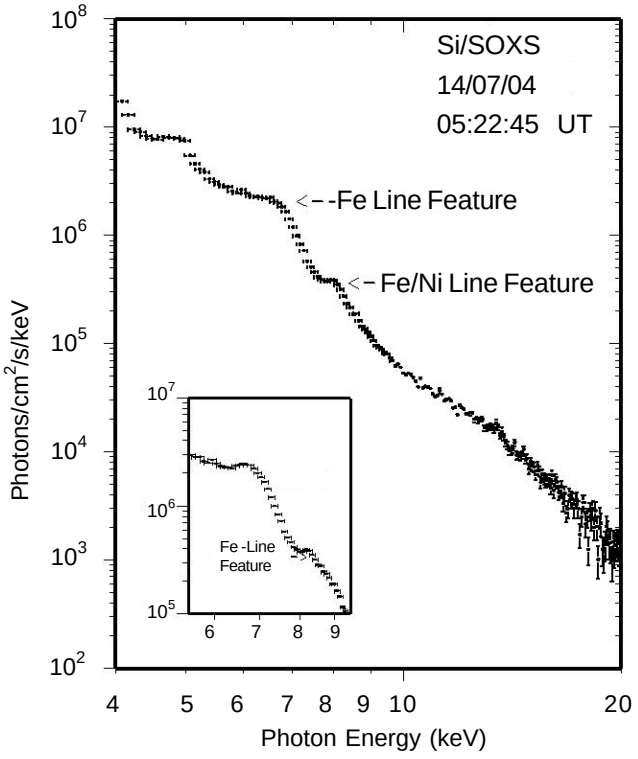


Fig. 3.4 : X-ray photon spectra of July 14, 2004 solar flare as observed by Si detector of SOXS mission. The Fe and Fe/Ni line features show peaking around 6.7 and 8keV respectively and can be clearly seen in the inset. The spectrum beyond 10 keV is hard X-ray continuum caused by interaction of accelerated electrons with ambient solar material.

Energetics and Dynamics of March 10, 2001 Impulsive Solar Flare

An unusual impulsive flare was observed on March 10, 2001 in various wavebands. A detailed study of this flare was carried out using H-alpha observations from ARIES, Nainital, HXT, SXT observations from Yohkoh mission, and radio waveband observations from Nobeyama Radio Observatory to derive the energetics and dynamics of this impulsive flare. The H-alpha, SXR, HXR, MW and magnetogram images were co-aligned within the instrumental spatial resolution limit. A single HXR source was detected in this flare, which is found spatially associated with one of the H-alpha bright kernels. The unusual feature of this HXR source is the rotation during the impulsive phase in clockwise direction. It is proposed that the rotation may be due to the change of magnetic reconnection site. In MW emission two sources were found, a main source which is at the main flare site and the other, a remote source located in south-west direction. It appears that the remote source is formed by the impact of accelerated energetic electrons from the main flare site. From the spatial co-relation of multi-wavelength images of the different sources, it is concluded that this flare has three-legged structure and support the emerging flux model.

(Ramesh Chandra, Rajmal Jain**,** Wahab Uddin, Keiji Yoshimura, T. Kosugi, T. Sakao, Anita Joshi and M. R. Deshpande)

Closed Form Expressions of the First Born Amplitude for Transitions Connecting a Circular State to a State of Large (l, m)

In contrast to the conventional series expressions obtained by using spherical polar coordinates, we have shown that the use of cylindrical polar coordinates enables us to derive compact expressions of the first Born amplitude for some selected sets of transitions from an arbitrary initial circular $\left|\phi_{n_i,n_i-1,n_i-1}\right\rangle$ state to a final $\left|\phi_{n_f,n_i-l_i,m_f}\right\rangle$ state of large (l_f, m_f). The formulas for $\left|\phi_{n_i,n_i-1,n_i-1}\right\rangle \rightarrow \left|\phi_{n_f,n_f-1,n_f-2}\right\rangle$ and $\left|\phi_{n_i,n_i-1,n_i-1}\right\rangle \rightarrow \left|\phi_{n_f,n_f-1,n_f-3}\right\rangle$ transitions are expressed in terms of the Jacobi polynomials which serve as suitable starting points for constructing complete solutions over the bound energy levels of hydrogen-like atoms. The formulas for $\left|\phi_{n_i,n_i-1,n_i-1}\right\rangle \rightarrow \left|\phi_{n_f,n_f-1,n_f-2}\right\rangle$ and $\left|\phi_{n_i,n_i-1,n_i-1}\right\rangle \rightarrow \left|\phi_{n_f,n_f-1,n_f-3}\right\rangle$ transitions are in simple algebraic forms and are directly applicable to all possible values of n_i and n_f. It emerges that the method can be extended to evaluate the first Born amplitude for many other transitions involving states of large (l,m). The new formulae are free from the difficulties in numerical computation and mathematical analysis that are encountered with the conventional expressions for transitions between high Rydberg states.

(D.P. Dewangan)

A Quantum Mechanical Derivation of the Formula of the Correspondence Principle Method for Dipole Matrix Elements between Hydrogenic Stark States

Even before the advent of quantum mechanics, Born had exploited the Correspondence Principle (CP) to derive a formula for the x-component of the dipole matrix element between Stark states of hydrogen from the classical expression. We have been able to derive, for the first time, the Born CP formula starting from the corresponding quantum expression without appealing to any classical or semiclassical arguments. The derivation became possible because of a new approximation to the terminating hypergeometric function of large arguments that we had earlier obtained to determine the behaviour of quantum matrix elements for certain Rydberg transitions.

(D.P. Dewangan, Neerja and K. Basuchoudhury)

Classification of States in the SO(8) Proton-neutron Pairing Model

Isoscalar (T = 0) plus isovector (T = 1) pairing Hamiltonian in LS-coupling is solvable in terms of a SO(8) Lie algebra for three special values of the mixing parameter that measures the competition between these two pairing modes. Shell model Lie algebras, with only particle number conserving generators that are complementary to the three chains of subalgebras, as identified last year, are used in the classification of states for a given number of nucleons. The classification problem is solved explicitly (for any nucleon number), employing recent developments in the plethysm method in group theory, for states with SO(8) seniority v = 0, 1, 2, 3 and 4. Using them, band structures in isospin space are identified for states with v = 0, 1, 2 and 3. They give new insights into the structures generated by proton-neutron pairing in heavy N = Z nuclei.

(V.K.B. Kota and J.A. Castilho Alcaras)

Deformed Shell Model for N = Z Nuclei ^{52}Fe and ^{72}Kr

Deformed configuration mixing shell model with extension to include isospin projection (DSMT) for two and four particle configurations (generated by particle-hole excitations) is applied to study the structure of the low-lying T = 0, 1 and 2 bands (or levels) in the even-even N=Z nuclei ^{52}Fe and ^{72}Kr. The *pf* shell KB3 interaction for ^{52}Fe and a modified Kuo's interaction for ^{72}Kr are employed in the calculations. Lowspin ($J \leq 10$) members of the T = 0, 1 and 2 bands in ^{52}Fe are compared with experiment including the known E2 transition strengths. The agreement between DSMT and experiment is reasonably good. Similarly the low spin members of the observed (prolate) yrast band in ^{72}Kr are also well described

by DSMT. This analysis is being extended to N = Z+1 nuclei.

(V.K.B. Kota and R. Sahu)

SU(N) Wigner-Racah Algebra for Solving Embedded Gaussian Unitary Ensemble of Random Matrices

Embedded random matrix ensembles of k-body interactions are investigated mainly via numerical methods. Simplest of these ensembles is the embedded Gaussian unitary ensemble EGUE(*k*) for spin-less fermion systems. With *m* particle space dimension given by $N_m = \binom{m}{k}$ one has the unitary groups SU(N), $U(N_k)$ and $U(N_m)$ with EGUE(k) invariant under $U(N_k)$ and the embedding in m-particle spaces is defined by SU(N); note that a GUE in m particle spaces is invariant under $U(N_m)$ but not the EGUE(k), k < m. All the information about EGUE(k) is in the covariance matrix or the matrix of second moments. Extending some recent results due to Pluhar and Weidenmüller, we showed for the first time that the matrix elements of the matrix of second moments can be written explicitly in terms of SU(N) Wigner and Racah coefficients and used here is Biedenharn-Elliott sum rule extended to SU(N). These results give in a simple manner the formulas for the low order moments that define the state density and the bivariate moments that give information about fluctuations. Wigner-Racah algebra analysis of embedded ensembles with more general group symmetries should be possible in future, thus opening up a new direction in random matrix theory.

(V.K.B. Kota)

Regularities with Random Interactions in Energy Centroids Defined by Group Symmetries

Regular structures generated by random interactions in energy centroids defined over irreducible representations (irreps) of some of the group symmetries of the interacting boson models sdIBM, sdgIBM, sdIBM-T and sdIBM-ST of atomic nuclei are studied by deriving trace propagation equations for the centroids. Using these, energy centroids are calculated without recourse to the construction of the many boson Hamiltonian matrices. It is found that, with random interactions, the lowest and highest group irreps in general carry most of the probability for the corresponding centroids to be lowest in energy. This generalizes the result known earlier, via numerical diagonalization, for the more complicated fixed spin J centroids where simple trace propagation is not possible. Based on this work, it is conjectured that propagation equations may be useful in quantifying geometric chaos.

(V.K.B. Kota)

Chaos and Localization in Wavefunction Structures of Complex Atoms NdI, PmI and SmI

Wavefunctions of complex lanthanide atoms NdI, PmI and SmI, obtained via multiconfiguration Dirac-Fock method, are analyzed for density of states in terms of partial densities, strength functions ($F_k(E)$), number of principal components ($\zeta_2(E)$) and occupancies $\langle n_\alpha \rangle^E$ of single particle orbits using embedded Gaussian orthogonal ensemble of one plus two-body random matrix ensembles [EGOE(1+2)]. It is seen that density of states are in general multi-modal, $F_k(E)$'s exhibit variations as function of the basis states energy and $\zeta_2(E)$'s show structures arising from localized states. The sources of these departures from EGOE(1+2) are investigated by examining the partial densities, correlations between $F_k(E)$, $\zeta_2(E)$ and $\langle n_\alpha \rangle^E$ and also by studying the structure of the Hamiltonian matrices. These studies point out the operation of EGOE(1+2) but at the same time suggest that weak admixing between well separated configurations should be incorporated into EGOE(1+2) for more quantitative description of chaos and localization in NdI, PmI and SmI.

(Dilip Angom and V.K.B. Kota)

Transverse Beam Polarization and Limits on Leptoquark Couplings in $e^+e^- \to t\bar{t}$

It is shown that if electron and positron beams at a linear collider are transversely polarized, azimuthal asym-

metries of the final-state top quark in $e^+e^- \to t\bar{t}$ can be used to probe a combination of couplings of left and right chiralities in a scalar leptoquark model. The CP-violating azimuthal asymmetry which would provide a direct test of CP-violating phases in leptoquark couplings turns out to be too small because of the indirect limit on these phases from the electric dipole moment of the electron. The CP-conserving azimuthal asymmetry, however, would be a sensitive test of the chirality violating couplings. A linear collider operating at $\sqrt{s}$ = 500 GeV and having transverse polarizations of 80% and 60% respectively for the e^- and beams, can put a limit of the order of 0.025 e^2 on the product of the left and right chirality leptoquark couplings with a leptoquark mass of 1 TeV and for an integrated luminosity of 500 fb^{-1}.

(S.D. Rindani)

Transverse Beam Polarization and CP Violation in with Contact Interactions

We consider the most general gauge-invariant, chirality-conserving contact interactions in the process $e^+e^- \to \gamma Z$, of the type proposed by Abraham and Lampe, in order to explore the possibility of CP violation at future linear colliders in the presence of polarized beams. We hereby extend recent work on CP violation due to anomalous triple-gauge boson vertices. We isolate combinations of couplings which are genuinely CP violating, pointing out which of these can only be studied with the use of transverse polarization. We place constraints on these couplings that could arise from suitably defined CP-odd asymmetries, considering realistic polarization (either longitudinal or transverse) of 80% and 60% for the electron and positron beams respectively, and with an integrated luminosity Z dtL of 500 fb^{-1} at a centre of mass energy of = 500 GeV.

(B. Ananthanarayan and S.D. Rindani)

Quark Lepton Symmetry and Large Leptonic Mixing

Experimental results lead to a conclusion that mixing among quarks is small while two of the mixing angles among leptons are large. We propose a unified approach in which this fact comes out naturally. Quarks remain unmixed to leading order while mixing among leptons follows due to majorana nature of neutrinos. We consider detailed schemes for corrections to this approach. Unambiguous prediction appears to be rather large > 0.07 value for U_{e3}.

(A.S. Joshipura)

Parity Violation and Left-right Symmetry

Parity violation has been observed at low energy, but one expects that at higher energies there was no parity violation. The most appealing theory for such explanation is left-right symmetric extensions of the standard model of electroweak interactions. In these left-right symmetric theories parity could be violated either spontaneously or explicitly and both these scenarios may have interesting consequences, which we have studied.

(U. Sarkar)

SO_{10} Grand Unified Theories with Doublet Higgs Scalars

$e^+e^- \to t\bar{t}$

One natural extension of the standard model of particle physics is the grand unified theory, in which all the three gauge interactions: strong, weak and electromagnetic, are unified in one theory. One of the unified models, which can incorporate left-right symmetry at some intermediate scale, is the SO_{10} grand unified theory. We proposed a variant of the conventional SO_{10} grand unified theory with only doublet Higgs scalars, instead of including any triplet Higgs scalars. The details of this model are now being studied.

(U. Sarkar, G. Rajasekaran and B.R. Desai)

Contribution of U_{e3} to Geo-neutrino Flux

We show that a non-zero U_{e3} close to the CHOOZ bound $Sin^2\ 2\theta_{13}$ ~ 0.16 (90% CL) can change the geo-neutrino flux by 12%. Geo-neutrino detection in Kamland with a exposure of $3x10^{32}$ proton-years is sensitive to $Sin^2\ 2\theta_{13}$ to the level of 0.2(1σ). For the same exposure a detector close to Himalayas can probe $Sin^2\ 2\theta_{13}$ down

to 0.15(1σ) due to higher geo-neutrino flux from the Tibetan plate.

(S. Mohanty)

Sigma Model at Finite Temperature and Densities: A Self-consistent Approach

We consider phase diagram of linear sigma model coupled to quarks at finite temperatures and baryon densities. At the tree level this model shows chiral symmetry breaking at zero temperature and zero density. At finite baryon densities chiral symmetry is restored through a first order phase transition at zero temperature. At finite temperature and at zero baryon density it shows a second order phase transition. The tricritical point (Tc μc) , within the model turns out to be about (99,207) MeV. We examine here the effect of quantum fluctuation as well as thermal fluctuation on the phase diagram of this model using nonperturbative variational methods in quantum field theory for such a many body system.

(H. Mishra and A. Mishra)

Currents and Magnetic Field around a Young Stellar Object: Effect of Neutral Gas and Charged Dust Dynamics

The effect of neutral gas dynamics is introduced in a model for the generation of current and strong azimuthal magnetic field around a young stellar object whose weak dipole-like magnetic field is threaded into the gas and the charged dust of the accretion disc around it. Considering the motion of ions and charged dust in presence of neutral gas, it is shown that the sheared dust-neutral gas velocities can lead to current along the ambient magnetic field direction. This current may be strong enough to generate azimuthal magnetic field, which may become large to change the total magnetic field configuration at least near the strong sheared region. The currents along the field lines appear to be source of radiation and the complex structure of magnetic field provides helical type plasma motion from the disc to the polar region.

(A.C. Das)

Macroscopic Matter Waves in a Nano-tube

The propagation of quantum particles is considered in a nano-tube in the presence of axisymmetric scattering centers at specific points along the length of the tube. The scattering generates transition amplitude waves with origins at the scattering centres. These waves possess macroscopic matter wave length which is found to be in inverse proportion to particle de Broglie wave length. Such macroscopic matter waves have already been observed for the charged particle dynamics in a magnetic field.

(R.K.Varma and Tito Mendonca)

Quantum Mechanics in the Correspondence Limit from the Classical Liouville Equation: The Forced Square Well

We demonstrate here the derivation of the equation of evolution for the quantum mechanical transition amplitudes in the correspondence limit, starting from the classical Liouville equation, and without any quantum mechanical input. The illustrative example used here is that of a forced square well with free motion in the perpendicular direction. The procedure employed amounts to constructing a Hilbert space representation of the Liouville equation used earlier.

(R.K. Varma and Tito Mendonca)

The Correspondence Limit Quantum Forced Hydrogen Atom from the Classical Liouville Equation

We obtain the equation of evolution for the transition amplitude in the correspondence limit from the Schrödinger equation for the forced hydrogen atom. The same equations are next derived from the classical Liouville equation without any quantum mechanical input. This shows that the transition amplitude in the correspondence limit serve as the bridging wave mechanical objects which are also classical objects and are in fact, found to exhibit matter wave behaviour in the macroscopic dimensions.

(R. K. Varma and Tito Mendonca)

Macroscopic Matter Wave Interference Effects with Inelastic Double Slit

We consider the case of an inelastic double slit as against the standard elastic double slit which has served as the paradigm for the interference with quantum particles. We exhibit here a new kind of interference effect that arises in the case of an inelastic double slit where the incident electrons can be scattered by some bound systems (atoms or molecules) at the site of the slits. The scattering by these systems generates transition amplitudes at each of the slits. These transition amplitude waves which have macroscopic matter waves associated with them then interfere at the observation screen leading to macroscopic matter wave interference effects. The macroscopic matter wave length can be several orders of magnitude larger than the de Broglie wave length.

(R.K. Varma)

Schrödinger equation for a Particle in a Static Magnetic Field and a Radiation Field in the Number Representation: Quantum Theory for the Ponderomotive Potential

We derive an equation of evolution in the number representation for electrons in a static magnetic field and a radiation field, starting from the Feynman path integral formalism for the particle. The equation of evolution so obtained, in fact furnishes a quantum theory for the ponderomotive potential which arises in the second order perturbation theory. The formalism developed yields in the process two adiabatic invariants of the system: the gyroaction for the charged particle in the staic magnetic field, modified by the presence of the radiation field, and the photon occupation number. The equations obtained can, however, describe the nonadibatic effect as well.

(R.K. Varma)

Chiral Crystalization in Quark Matter

In the interior of neutron stars the quark matter that exists, it is likely to have pairing of quarks or quark antiquarks with differing chemical potential. We consider here paring of quark and antiquarks with nonzero total momentum. Condensates of this sort spontaneously break translational and rotational invariance with a periodic structure. Explicitly this is described by a standing wave in scalar and pseudoscalar channel and entirely reflects many body effects. Magnetic properties of such a state are also elucidated.

(H. Mishra and A. Mishra)

Coupled Chaotic Dynamics on Networks

We study the synchronization of coupled dynamical systems on a variety of networks. The dynamics is governed by a local nonlinear map or flow for each node of the network and interactions connecting different nodes via the links of the network. For small coupling strengths nodes show turbulent behaviour but form synchronized clusters as coupling increases. When nodes show synchronized behaviour, we observe two interesting phenomena. First, there are some nodes of the floating type that show intermittent behaviour between getting attached to some clusters and evolving independently. Secondly, we identify two different ways of cluster formation, namely self-organized clusters, which have mostly intra-cluster couplings and driven clusters, which have mostly inter-cluster couplings.

(S. Jalan and R.E. Amritkar)

Relative Entropy of Chaotic Dynamical Systems

We use the concept of relative entropy to distinguish between data sets generated by different chaotic systems. The chaotic data sets are generated for different well known chaotic dynamical systems (both discrete and continuous) and different parameter values. Each data set is suitably discretized and converted into a sequence of symbols. The relative entropy is evaluated using an algorithm based on Lempel-Ziv compression technique. The relative entropy successfully picks out the dynamics of the given unknown data from those of the known ones in most cases. Therefore, the results indicate that a suitable discretization is representative of the dynamics inherent in the chaotic time series. We demonstrate the practical utility of our method by apply-

ing it to sun spot data. Our analysis shows that there is considerable difference at the micro-structural level between sunspot values near different maxima of sunspot activity while there are considerable similarities between different minima.

(K.B.K. Mayya and R.E. Amritkar)

Stochastic Dynamical Model for Stock-stock Correlations

We propose a model of *coupled random walks* for stock-stock correlations. The walks in the model are coupled via a mechanism where the displacement (price change) of each walk (stock) is obtained by the price gradients over some underlying network. We assume that the network has two underlying structures, describing the correlations among the stocks of the whole market and among those within individual groups, respectively, each with a coupling parameter controlling the degree of correlation. The model provides the interpretation of the features displayed in the distribution of the eigen values for the correlation matrix of real market on the level of time sequences. We verify that such modelling indeed gives good fit for the market data of US stocks.

(R.E. Amritkar, W.J. Ma and C.K. Hu)

Perturbed Hartree-Fock Potential in Coupled-cluster Framework

Inter-electron interaction in atoms other than the Coulomb interaction modify the Hartree-Fock potential or the Dirac-Fock potential in the relativistic description. The modified potential is referred to as coupled perturbed Hartree-Fock potential and it is the leading term contributing to atomic properties arising from weak interaction, P and T violating interactions, etc. We have shown the equivalence of terms in coupled perturbed Hartree-Fock with selected terms in coupled-cluster method. The equivalence is demonstrated using many-body diagrams and analytically. The equivalence is incomplete as the wave operator in the normal coupled-cluster is non-hermitian but it is complete in Hermitian approach like unitary coupled-cluster. We have carried out a thorough study of the contributions from each term, choice of basis and effect of high angular momentum single electron wave-functions.

(Dilip S. Angom, K. V. P. Latha, Rajat K. Choudhary, B. P. Das and Debashis Mukherjee)

An All Order Properties Calculation in Coupled-cluster

In the coupled-cluster method widely used in many-body calculations, the wave operator is exponential. Consequently, the expression of properties calculated from the coupled-cluster wave function has infinite terms. In practice the series is truncated after a certain order, which is justified as the contribution from the higher order terms is negligible. However, the order at which the series is truncated can depend on the property. An alternative approach is to develop an iterative method, it is shown that this is indeed possible. The method is general and can be implemented to avoid truncations in other methods like unitary coupled cluster. It is based on the separation of the terms in the properties calculations into connected and disconnected terms, then contracting with cluster operators to yield higher order contributions.

(Dilip S. Angom)

Configuration Interaction Calculations of Atomic Yb Properties

Atomic Yb is a promising candidate to measure atomic parity nonconservation effects, which can probe physics beyond the standard model in particle physics. The theoretical atomic structure calculation is a challenge as the high angular momentum valence electrons leads to extremely large configuration space. A series of large scale configuration interaction calculations demonstrate the importance of core polarization effects. The calculations were carried out using the NERSC supercomputer seaborg (one of the fastest computer in the world). The calculations showed the core-polarization effect is largest in 5p and, the double excitations from 4f and the effects of excitations to higher angular momentum g orbitals are negligible. Subsequently the electric dipole transition amplitudes are also calcualted.

(Dilip S. Angom, D. Budker and B.P. Das)

Electrodynamics in Rotating Coordinates

The 1908 paper of Einstein and Loeb on the unipolar induction relating to the electrodynamics of moving media had generated some controversy between theory and experiment. Basically the work involved relates to the electrodynamical parameters in rotating coordinates. We analyse this with a new setting differentiating between the geometrical quantities and the associated physical quantities through a tetrad formalism. The analysis so obtained could be of interest in the context of Pulsar electrodynamics.

(A.R. Prasanna & N. Kumar)

Nonminimal Electrodynamics

Continuing our discussions of the nonminimal coupling of electromagnetism and gravity using the extra coupling $l\, R_{hijk}\, F^{hi}\, F^{jk}$ alongwith the usual Einstein - Maxwell Lagrangian , Prasanna had obtained the extended set of Field equations (1973) which has attracted some interest in recent times. We are now investigating the possible contribution from the l term in solution relating to the external field of a charged mass, assuming the usual Reissner Nordstrom metric for the minimal contribution. The extra information from the nonminimal coupling could have implications in the analysis of Hawking temperature and the blackhole entropy of charged bodies.

(A. R. Prasanna , K. Bhattacharya and S.Mohanty)

The summary of the research activities of this division over the past year is as follows.

Vacuum-induced Stark Shifts for Quantum Logic

A collective system of atoms in a high-quality cavity can be described by a nonlinear interaction which arises due to the Lamb shift of the energy levels due to the cavity vacuum. It is shown how this collective interaction can be used to perform quantum logic. In particular schemes are produced to realize controlled-NOT gates not only for two-qubit but also for three-qubit systems. Realizations of Toffoli gates have been discussed. Effective Hamiltonian is also realized in other systems such as trapped ions or magnetic molecules.

(A. Gábris and G.S. Agarwal)

Quantum Logic Gates using Stark-shifted Raman Transitions in a Cavity

A scheme to realize the basic two-qubit logic gates such as the quantum phase gate and the controlled-NOT gate using a detuned optical cavity interacting with a three-level Raman system, is presented. The role of Stark shifts, which are as important as the terms leading to the two-photon transition is discussed. The operation of the proposed logic gates involves metastable states of the atom and hence is not affected by spontaneous emission. These ideas can be extended to produce multiparticle entanglement.

(A. Biswas and G.S. Agarwal)

Langevin Analysis of Fundamental Noise Limits in Coherent Anti-Stokes Raman Spectroscopy

A Langevin approach is used to analyze the quantum noise in coherent anti-Stokes Raman spectroscopy in several experimental scenarios: with continuous-wave input fields acting simultaneously and with fast sequential pulsed lasers where one field scatters off the coherence generated by other fields and for interactions within a cavity and in free space. In all cases, the signal and quantum noise due to spontaneous decay and decoherence in the medium are shown to be described by the same general expression. It is shown in particular that for short interaction times, the medium noise is not important and the efficiency is limited only by the intrinsic quantum nature of the photon.

(K.K. Das, G.S. Agarwal, Yu.M. Golubev and M.O. Scully)

Inducing Disallowed Two-Atom Transitions with Temporally Entangled Photons

Two uncoupled two-level atoms cannot be jointly excited by classical light under general circumstances, due to destructive interference of excitation pathways in two-photon absorption. However, with temporally entangled light, two-atom excitation is shown possible. Photons arising from three-level cascade decay are intrinsically ordered in time of emission. This field correlation induces a joint resonance in the two-atom excitation probability via suppression of one of the time-ordered excitation pathways. The relative gain in two-photon absorption increases with the time-frequency entanglement.

(A. Muthukrishnan, G.S. Agarwal and M.O. Scully)

Nonclassical Imaging for a Quantum Search of Trapped Ions

A simple search problem which can be pursued with different methods, either on a classical or on a quantum basis is discussed. The system is represented by a chain of trapped ions. The ion to be searched for is a member of that chain, consisting, however, of an isotopic species different from the others. It is shown that classical imaging may lead to the final result as fast as quantum imaging. However, for the discussed case the quantum method gives more flexibility and higher precision when the number of ions considered in the chain increases. In addition, interferences are observable even when the distances between the ions are smaller than half a wavelength of the incident light.

(G.S. Agarwal, G.O. Ariunbold, J. von Zanthier and H. Walther)

Interior Gap Superfluidity in a Two-component Fermi Gas of Atoms

A new superfluid phase in Fermi matter, termed as “interior gap” (IG) or “breached pair”, has been recently predicted by Liu and Wilczek. This results from pairing between fermions of two species having essentially different Fermi surfaces. Using a nonperturbative variational approach, we analyze the features, such as energy gap, momentum distributions, and elementary excitations, associated with the predicted phase. A possible realization of this phase in two-component Fermi gases in an optical trap is discussed.

(B. Deb, A. Mishra, H. Mishra and P.K. Panigrahi)

The Einstein-Podolsky-Rosen Paradox on a Lattice

A possible realization of the position- and momentum-correlated atomic pairs that are confined to adjacent sites of two mutually shifted optical lattices and are entangled via laser-induced dipole-dipole interactions is studied. The Einstein-Podolsky-Rosen (EPR) “paradox” with translational variables is then modified by lattice-diffraction effects. This “paradox” can be verified to a high degree of accuracy in this scheme.

(T. Opartný, M. Kolár, G. Kurizki, and B. Deb)

Scalable Deutsch-Jozsa Algorithm using Atomic Ensemble

A physical model for implementation of the scalable version of the Deutsch-Jozsa algorithm is proposed. This model uses Stark shifts of the ground states in an ensemble of atoms and sources of photons on demand. The photons dispersively interact with the ensemble, leading to an effective Hamiltonian in atom-field basis, which is useful for performing the required two-qubit operations. Combining these with a set of one qubit operations, the algorithm can be implemented. We have studied the experimental feasibility of the proposal (**Fig. 5.1**).

(S. Dasgupta and G. S. Agarwal)

Inseparability Inequalities for Bipartite Non-Gaussian states

The necessity of inseparability inequalities involving higher-order correlation is exploited for bosonic non-Gaussian states. A particular example of non-Gaussian state, which is a bipartite entangled state of the Bell form is studied in this context. It is shown that, the existing criteria for inseparability, based on second order correlations can not efficiently detect the entanglement of these states. New inequalities involving higher-order correlation, for testing entanglement in such non-Gaussian

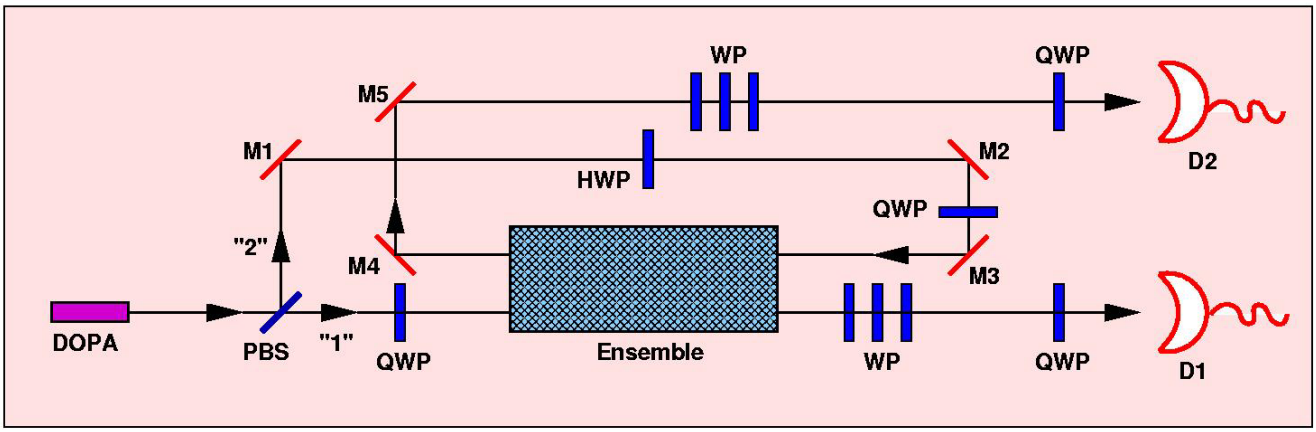


Fig. 5.1 A possible experimental set-up for implementing the two-bit Deutsch-Jozsa algorithm. DOPA - degenerate optical parametric amplifier, PBS - polarization beam splitter, M1 etc. - lossless mirrors, D1, D2 - polarization detectors, HWP - half-wave plate, QWP - quarter-wave plate, WP - sequence of quarter and half-wave plates.

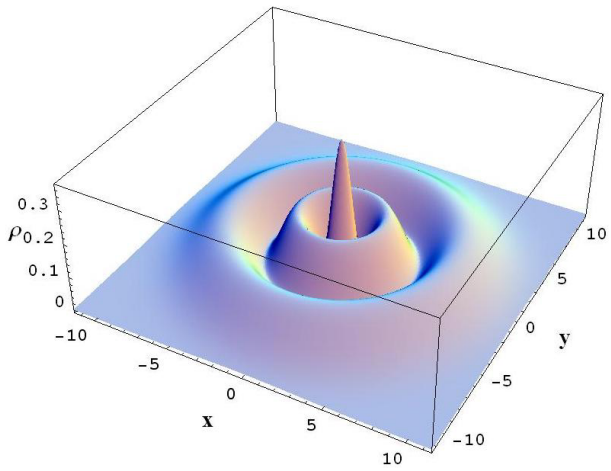


Fig. 5.2 Figure depicting information entropy density of attractive planar Hooke's atom.

states have been derived. These inequalities can also be tested in optical experiments.

(G.S. Agarwal and A. Biswas)

Information Entropy and Correlation of the Hooke's Atom

An algebraic procedure to find the eigenstates of two-charged particles in an oscillator potential, known as Hooke's atom is shown. For the planar Hooke's atom, the exact eigenstates and single particle densities for arbitrary azimuthal quantum number, are obtained analytically. Information entropies associated with the wave functions for the relative motion are then studied systematically, since the same incorporates the effect of the Coulomb interaction. The quantum pottery of the information entropy density reveals a number of intricate structures, which differ significantly for the attractive and repulsive cases. The procedure to obtain the approximate eigen states is indicated. Making use of the relationship of this dynamical system with the quasi-exactly solvable systems, one can also develop a suitable perturbation theory, involving the Coulomb coupling , for the approximate wave functions **(Fig. 5.2)**.

(R. Atre, C.S. Mohapatra and Prasanta K. Panigrahi)

Quantum Interferences from Cross Talk in J=1/2 ↔ J=1/2 Transitions

The possibility of a control field opening up multiple pathways and thereby leading to new interference and coherence effects is considered. The idea has been illustrated by considering the J=1/2 ↔ (J=1/2 transition. As a result of the additional pathways, the possibilities of nonzero refractive index without absorption and gain without inversion have been shown. These results in terms of the coherence produced by the opening of an extra pathway have been explained.

(S. Dasgupta)

Large Two-atom Two-photon Vacuum Rabi Oscillations in a High-quality Cavity

A large cooperative effect involving two-atom two-photon vacuum Rabi oscillations in a high-quality cavity is predicted. The two-photon emission occurs as a result of simultaneous de-excitation of both atoms with two-photon resonance condition $\omega_1 + \omega_2 \sim \omega_a + \omega_b$, where ω_1 , ω_2 are the atomic transition frequencies and ω_a ,ω_b are the frequencies of the emitted photons. The actual resonance condition depends on the vacuum Rabi couplings. The effect can be realized either with identical atoms in a bimodal cavity or with nonidentical atoms in a single-mode cavity.

(P.K. Pathak and G.S. Agarwal)

dc-field-induced Enhancement and Inhibition of Spontaneous Emission in a Cavity

It is demonstrated how spontaneous emission in a cavity can be controlled by the application of a dc field. The method is especially suitable for Rydberg atoms. A simple argument based on Stark shifts for the control of emission is presented.

(P.K. Pathak and G.S. Agarwal)

Causality in Propagation of a Pulse in a Nonlinear Dispersive Medium

The causal propagation of the pulse through dispersive media by very precise numerical solution of the

coupled Maxwell-Bloch equations without any approximations about the strength of the input field is investigated. Full nonlinear behaviour of the pulse propagation through solid state media like ruby and alexandrite is studied. It is demonstrated that the information carried by the discontinuity, i.e. front of the pulse moves inside the media with velocity C even though the peak of the pulse can travel either with sub-luminal or with superluminal velocity. The numerical demonstration is subject to the condition that the background refractive index of the medium is unity. The argument of Levi-Civita is extended to prove that the discontinuity would travel with velocity C even in a nonlinear medium.

(G.S. Agarwal and T.N. Dey)

Propagation of a Phase Flipped Gaussian Beam through a Paraxial Optical ABCD System

Using the Huygens'-Fresnel diffraction integral, a closed-form analytic expression for the amplitude distribution of a phase flipped Gaussian (PFG) beam passing through a paraxial optical ABCD system is obtained. The resulting expression is related in a simple way to the corresponding expression for a Gaussian beam and contains error functions of complex amplitude. Both ideal and non-ideal PFGs are considered. Numerical results are presented for the special case of free-space propagation. Intensity patterns of the propagating PFG are explained by means of the power series and asymptotic expansions of the error function.

(J. Banerji)

On Polynomial Solutions of Heun Equation

By making use of a recently developed method to solve linear differential equations of arbitrary order, a wide class of polynomial solutions to the Heun equation have been found. The series solution to the Heun equation before identifying the polynomial solutions has been constructed. The Heun equation extended by the addition of a term, $-\sigma / x$, is also amenable for polynomial solutions.

(N. Gurappa and Prasanta K. Panigrahi)

Induced Magnetic Moment in Noncommutative Chern-Simons Scalar QED

The one loop, $O(\theta)$ correction to the vertex in the noncommutative Chern-Simons theory with scalar fields in the fundamental representation is computed. Emphasis is placed on the parity odd part of the vertex, since the same leads to the magnetic moment structure. It is found that, apart from the commutative term, a θ -dependent magnetic moment type structure is induced. In addition to the usual commutative graph, cubic photon vertices also give a finite θ-dependent contribution. Furthermore, the two two-photon vertex diagrams, that give zero in the commutative case yield finite θ -dependent terms to the vertex function.

(P.K. Panigrahi and T. Shreecharan)

Wavelet Analysis and Scaling Properties of Time Series

A wavelet based method for the characterization of the scaling behavior of non-stationary time series is proposed. It makes use of the built-in ability of the wavelets for capturing the trends in a data set, in variable window sizes. Discrete wavelets from the Daubechies family are used to illustrate the efficacy of this procedure. After studying Gaussian white noise with the present and earlier approaches of detrending for comparison, the NASDAQ composite index for its multi-fractal behavior is analyzed.

(P. Manimaran, P.K. Panigrahi and J.C. Parikh)

Diagnosis of Human Breast Cancer through Wavelet Transform of Polarized Fluorescence

Wavelet transform of polarized fluorescence spectroscopic data of human breast tissues is found to reliably differentiate normal and malignant tissue types and isolate characteristic biochemical signatures of cancerous tissues, which can possibly be used for diagnostic purpose. A number of parameters capturing spectral variations and subtle changes in the diseased tissues in the visible wavelength regime are clearly identifiable in the wavelet domain. These investigations, corroborated with

tissue phantoms, indicate that the observed differences between malignant tumor and normal samples are primarily ascribable to the changes in concentration of porphyrin and density of cellular organelles present in tumors.

(N.C. Biswal, S. Gupta, A. Pradhan and P.K. Panigrahi)

Depolarization of Light in a Multiply Scattering Medium

The influence of the refractive index and size parameter of a scatterer on the depolarization of linearly and circularly polarized light in a turbid medium is investigated. The results show that for a given refractive index of the surrounding medium, the influence of the refractive index of the scatterer on the polarization of both linearly and circularly polarized light is rather weak for samples with smaller-sized scatterers. For a given value of optical thickness, the depolarization of the circularly polarized light was observed to be higher than that of linearly polarized light for these samples. In contrast, for samples prepared using larger-sized scatterers, linearly polarized light was observed to depolarize much faster than the circularly polarized light when the refractive index of scatterers was large (n=1.59) but no appreciable difference in depolarization of linearly and circularly polarized light was observed when the refractive index of scatterers had a lower value (n=1.37). Further, for scattering samples having Mie scatterers, for comparable value of optical thickness and anisotropy parameter, depolarisation of polarized light was much higher for samples with scatterers of lower refractive index.

(R.P. Singh, V.K. Jaiswal, A. Pradhan, S. Gupta, N. Ghosh and P.K. Gupta)

Axial Nature of an Optical Vortex

For angular momentum spectra of the vortex it is important to know if the vortex is axial or non-axial. We show that, the Wigner distribution can provide a solution, being different for axial and non-axial vortex.

(R.P. Singh, S. Roychowdhury and V.K. Jaiswal)

Lower Atmosphere

Ozone and Related Trace Gases Observed during the Land Campaigns

PRL participated in two land campaigns conducted as a part of the ISRO-GBP to study transport and transformation of pollutants over the Indian region. The first campaign was in February, 2004, covering mostly the southern peninsular Indian region. Seven teams participated and made measurements of aerosols and trace gases over this region. We have made measurements of surface ozone at eight selected sites between Ahmedabad and Hyderabad including Shadnagar near Hyderabad. Additional air samples collected from each site have been analysed at PRL for trace gases like CO, CH_4, NMHCs etc. We have observed higher ozone levels at all the eight remote stations than at Shadnagar and Ahmedabad. Also these levels are higher during return leg than during onward leg. The Shadnagar noon ozone values are in the range of 60-65 ppbv and the maximum average values during onward and return legs at remote sites are respectively 73 and 91 ppbv supporting our earlier findings that net surface ozone production at urban sites is lower. Also measurements of vertical ozone distributions upto 2.5km around Hyderabad using NRSA's aircraft on two days showed very high ozone of 70-100 ppbv.

The second land campaign was conducted over the Indo-Gangetic plain in December, 2004. Eight stations from Hisar to Kharagpur were selected in this region. Surface measurements of ozone and related trace gases at Hisar as well as at Kanpur were made. We also made balloon ascents from Kanpur for ozone, temperature and humidity profiles. Episodes of higher concentrations of CO, NO_x and also other pollutants have been observed at Hisar as well as at Kanpur. While clear diurnal variations in O_3, CO and NO_x were observed on normal days, they were disturbed on foggy days. Day time ozone values touched 80 and 70 ppbv respectively at Hisar and Kanpur.

(S. Venkataramani, K.S. Modh, T.A. Rajesh, L.K. Sahu, Shilpy, Y. B. Acharya and S. Lal)

Seasonal Changes in the Vertical Distribution of Ozone

Vertical distributions of ozone, temperature, humidity and winds are being measured fortnightly over Ahmedabad using balloon borne sensors since April, 2003. **Fig. 6.1** shows average ozone profiles in four different seasons over Ahmedabad. Large variations are observed not only in the stratospheric ozone near and above the peak concentration but also in the planetary boundary layer (PBL) and the free troposphere. The peak ozone concentration (given in partial pressure) occurs at around 26 km in the summer season and minimum around 16 km just below the tropopause. Highest ozone in the PBL, occurs in the winter (DJF) and fall (SON) seasons and minimum in the monsoon/summer season. However, it is surprising to note that this trend reverses in the free troposphere above 3 km height.

(Shilpy, S. Venkataramani, T. A. Rajesh, K. S. Modh, T. K. Sunil Kumar, S. Desai and S. Lal)

Budget of Trace Gases in the TTL using a 3D Chemical Transport Model

Distribution and budget of trace gases have been studied in the the Tropical Tropopause Layer (TTL), which is the transition region around the tropical tropopause

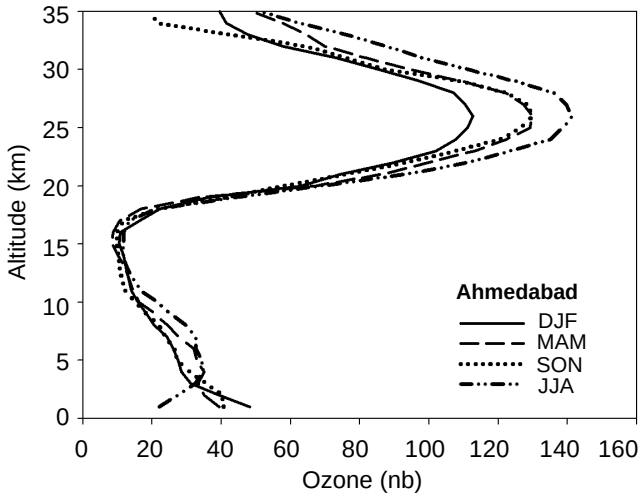


Fig. 6.1: Average seasonal distribution of ozone observed over Ahmedabad using balloon borne sensors. The alphabets refer to months of the year.

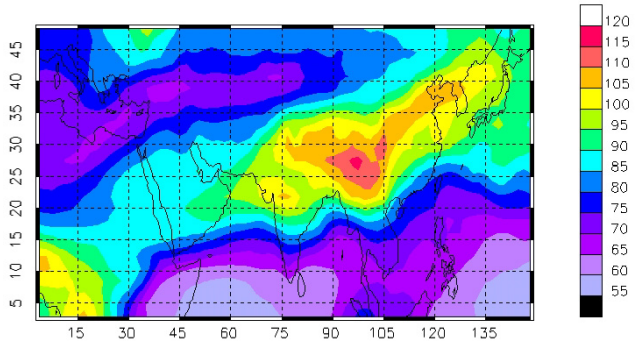


Fig. 6.2 : Monthly mean CO concentration for August, 2001 at 351 hPa from the model simulations.

(~12-17 km), using a 3D Chemical Transport Model called MOZART (Model for OZone And Related Chemical Tracers). **Fig. 6.2** shows model simulated CO for August, 2001 at about 351 hPa in the TTL. Relatively high values of CO can be seen over the Indian subcontinent. The model simulation shows a similar scenario for methane (CH_4) and ozone (O_3) and other trace gases. For the year 2001, we have calculated the monthly mean changes in mass for each species for the entire TTL, due to each of the processes – advection, chemistry, convection and diffusion. The contributions of advection and chemistry are dominant over convection and diffusion in changing the total mass of most of the trace species like CO, CH_4, O_3, NO_x. There is a significant variation in the contribution due to convection with two peaks in May-June and August-September, corresponding to deep convective events during the Asian summer monsoon. For ozone, convection and advection decrease its concentration in the TTL, unlike CO and CH_4, due to air with lower level of ozone coming from the troposphere. This work is done in collaboration with Max Planck Institute for Meteorology, Hamburg, Germany.

(Varun Sheel)

Aerosol Properties over Central India Studied as Part of the ISRO-GBP Land Campaign

Measurements of aerosol characteristics over central India were made at 18 selected locations during the ISRO GBP first land campaign. The measurements included the vertical profiles of aerosols using the mobile Micro Pulse Lidar (MPL), aerosol columnar optical depth, aerosol mass and number concentrations, aerosol scattering coefficient and the mass concentration of absorbing aerosol particles. The columnar aerosol optical depth (AOD) values are found to vary over different sites. Also, the AOD values are higher at shorter wavelengths and lower at longer wavelengths, which are expected when the aerosol population is dominated by sub-micron size particles. Large variations are seen in the aerosol profiles up to about 3 km altitude, a region that is directly influenced by surface processes and to a lesser extent by the long distance transport processes. The concentration of the absorbing aerosol particles are found to vary between 800 and 2600 ng/m^3. The single scattering albedo computed from these measurements show values in the range of 0.75 to 0.9. In general the pilot road campaign has revealed that even the background level aerosol properties in the remote continent regions in India can vary within a relatively short spatial extent of few hundred kilometers and within a few weeks, which could have a direct bearing on the aerosol radiative forcings. Aircraft based measurements of aerosol extinction profile were carried out for the first time in India during the campaign using aircraft from NRSA, Hyderabad. Results show that the urban produced aerosols are mainly confined to lower altitudes, up to about 2 km height, but they are found to disperse horizontally to large distances up to about 150 km.

(A. Jayaraman, H. Gadhavi, D. Ganguly, A. Misra, T.A. Rajesh, and S. Ramachandran)

Experimental Investigation of Aerosol Properties and Modelling its Impact on Radiation Budget

A state of the art mobile micro pulse Lidar (MPL) is used extensively to study the vertical distribution of aerosol properties and their changes caused due to changes in meteorological parameters such as relative humidity. Using both the observed aerosol optical properties and model computations, the aerosol radiative forcing is computed and studied in detail over different regions and seasons. It is shown that both the aerosol properties and the reflectance of the underlying surface play important

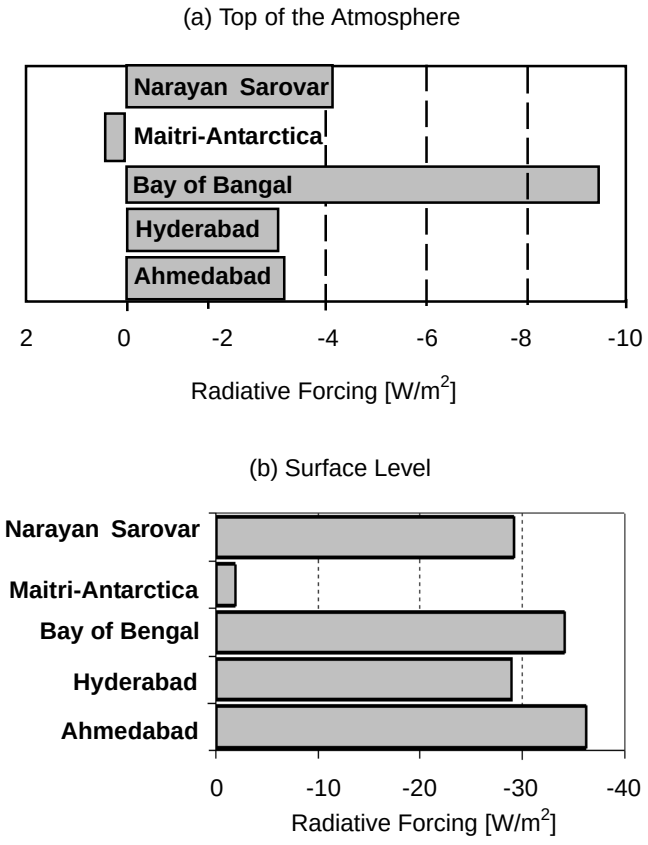


Fig. 6.3 : Aerosol radiative forcing computed over different locations. Upper part shows the radiative forcing at top of the atmosphere (TOA) and lower part shows radiative forcing at surface level

roles in determining both the magnitude and sign of the radiative forcing. **Fig. 6.3** shows the aerosol radiative forcing at different locations studied in this work. Aerosol radiative forcing over Ahmedabad at surface level is found to be -36.3 W/m^2 during February 2003, which is comparable to that observed over other regions for example near western coast of India (-27.0 W/m^2) and Bay of Bengal (-34.0 W/m^2) during same season. Similarly, aerosol radiative forcing over Maitri at surface level is found to be -1.91 W/m^2, which is quite comparable to that over southern Indian Ocean (-1.98 W/m^2). However, large difference is found in aerosol radiative forcing at the top of the atmosphere (TOA), where it depends not only on aerosol properties but also on the surface reflectance of the location. Over Ahmedabad, variation in meteorological parameters, such as relative humidity at upper altitudes, during the summer monsoon period is found to play a major role in altering the aerosol optical properties and hence the vertical profile of the radiative forcing.

(H. Gadhavi and A. Jayaraman)

Features in Wavelength Dependence of Aerosol Absorption Observed over Central India

Measurements on spectral dependence of aerosol light absorption and black carbon (BC) mass concentrations were made at different locations between Ahmedabad (23.03^{o}N, 72.5^{o}E) and Hyderabad (17.47^{o}N, 78.45^{o}E) in two phases during February, 2004. Distinctly different features in the wavelength dependence of light absorption by aerosols were observed at different stations indicating differences in aerosol composition. Average concentration of BC is about 2μgm^3 which is in the range of 2 to 5% of the total aerosol loading at the surface. Absorption Angstrom coefficient estimated using the relation $\beta_{abs}(\lambda) = K\,\lambda^{-\alpha}$ is found to vary between 1.2 to 2.0. Our result shows an excess absorption of up to 30% in the lower wavelength region (< 880 nm), different than typical λ^{-1} dependence exhibited by aerosols produced from fossil fuel combustion. This is explained by the presence of additional absorbing aerosols emitted from biomass and biofuel burnings.

(D. Ganguly, A. Jayaraman, H. Gadhavi and T.A. Rajesh)

Study of Aerosol Properties during Fog Events from Satellite and Ground Based Observations

The present work is a part of the second ISRO-GBP land campaign conducted at Hisar (29^{o}8'N, 75^{o}42'E), Haryana, from 1 to 31 December, 2004. A Quartz Crystal Microbalance (QCM) was used to measure the aerosol mass concentration in 10 different size ranges from 0.05 to 25 μm. The aerosol optical depth (AOD) at 400, 497, 668, 750 and 875 nm were measured by means of a hand-held sun-photometer. The Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the NASA satellites Terra and Aqua provided the space borne measurements. The correlation between the satellite derived AOD values averaged over

a 0.5^o x 0.5^o box centered over Hissar and the ground truth data sets is found to be very poor, the difference being larger for foggy days stressing the role of relative humidity in the satellite retrieval algorithms. A procedure for retrieval of AOD from satellite radiances under high humidity condition is developed taking into account the change in aerosol scattering phase function for different humidity conditions and for different aerosol types.

(A. Misra, S.K. Das and A. Jayaraman)

Characteristics of $PM_{2.5}$ Mass Concentrations over the Arabian Sea and Indian Ocean during Winter Monsoon

$PM_{2.5}$ aerosol mass particles, with aerodynamic diameters < 2.5μm) measured using a QCM impactor onboard ship cruises conducted during the winter monsoon seasons of 1996-2000 are analyzed. Frequency distribution plots show that over 28% of the days in coastal India, $PM_{2.5}$ are in the 60 - 80μgm^{-3} range and less than 40% of the values are in the 20 - 40μgm^{-3} bin. Over the Arabian Sea dominant range of $PM_{2.5}$ is found to be 40-60 μgm^{-3} peaking at 42%. Over the tropical Indian Ocean $PM_{2.5}$ values are found to peak in the 0-20μgm^{-3}at 33% (**Fig. 6.4**). It is found that about half the days over coastal India and 20% of the days over Arabian Sea and the tropical Indian Ocean, $PM_{2.5}$ exceeds the healthy condition limit of 65 μgm^{-3} indicating the influence of anthropogenic activities and transport of submicron aerosols from the Indian subcontinent and the surrounding regions over these oceanic regions.

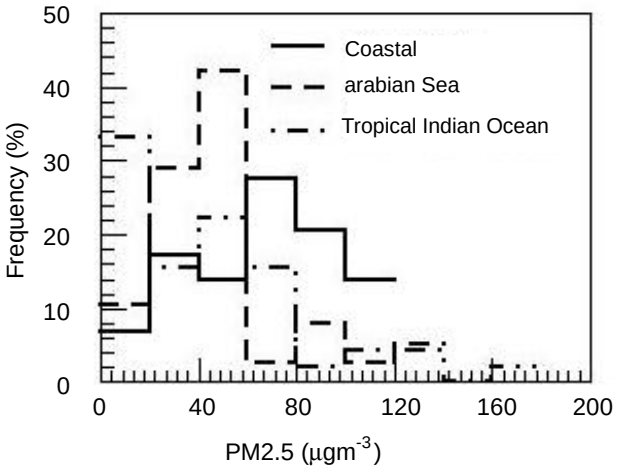


Fig. 6.4 : Frequency distributions of $PM_{2.5}$ mass concentrations over coastal India, the Arabian Sea and Tropical Indian Ocean.

(S. Ramachandran)

A GCM Study of Different Realizations of Anomalies in the Polar Winter Stratosphere due to Pinatubo Aerosol Perturbation

The effects of Pinatubo volcanic aerosols on the polar winter (PW) atmosphere are investigated from the perspective of different simulated realizations of the response of the climate system. A set of eight 2-year (mid-1991 to mid-1993) SKYHI General Circulation Model simulations starting from different initial conditions are performed. While the initial conditions employed have an influence upon the evolution of the PW stratospheric temperatures in the unperturbed state, the volcanic aerosol forcing can make the temperature less rather than more cold in the individual realizations relative to their own control. This is in contrast to a colder polar stratosphere obtained in all realizations when compared to the ensemble mean control. In all realizations, the equator-to-pole gradient becomes steeper, with the inverse correlation between tropical and polar temperature anomalies being reasonably consistent with the characteristics seen in a 50-year unperturbed model simulation. In a subset experiment where the stratospheric heating due to the aerosols is suppressed and only tropospheric cooling effects are present, some realizations no longer yield a colder winter stratosphere with respect to the ensemble mean. This suggests that aerosol-induced tropospheric gradient is a necessary but not a sufficient factor for making the winter polar stratosphere colder, and that the aerosol-induced stratospheric meridional gradient is also required. These results indicate that not only is the preconditioning of the atmosphere crucial, but that the stratospheric and tropospheric components of the radiative forcing shape the response in the high latitudes.

(S. Ramachandran and V. Ramaswamy)

Rayleigh Lidar Observations of Thermal Structure

Middle atmospheric thermal structure has been studied by using Rayleigh lidar data from 1998 to 2001 from Mt. Abu (24.5^{o} N, 72.7^{o} E) and Gadanki (13.5°N, 79.2°E). Comparison with CIRA-86 and MSISE-90 model showed that the lidar derived mean temperature profile is in close agreement with MSISE-90. Seasonal mean temperature profiles measured by lidar also have general agreement with the HALOE satellite data. The stratopause height and peak stratospheric temperature are found to be in the range of 42-58 km and 248 - 278 K, respectively. Using four years of Rayleigh lidar data collected from three different northern hemisphere stations (Mt. Abu , Gadanki and Observatoire de Haute Province (OHP; 44^{o}N, 6^{o}E)), the characteristics of double (seperated) stratopause have been studied for the first time. The normal stratopause is positioned at the center level of the double stratopause with its location nearer to the lower level of the double stratopause. The mean stratopause heights show higher values for Mt. Abu than Gadanki and OHP. The stratopause separation is found to be in the range of 2-8 km and centered around 4 -5 km and is higher for Gadanki than Mt. Abu and OHP. This work has been done in collaboration with NMRF, Gadanki and the University of La-reunion, France.

(Som Sharma, H. Chandra, A. Jayaraman and Y. B. Acharya)

Upper Atmosphere

Rocket and Ground-based Measurements of Mesospheric Turbulence

To understand the generation mechanism of mesospheric turbulence and its effects, simultaneous measurements of winds and electron/ion density and fluctuations were made in the mesosphere and lower thermosphere using rocket and MST radar for the first time over Indian region. A RH-300 Mk-II rocket instrumented with fixed bias Langmuir probe and Spherical probe was launched from SHAR at 1142 hrs on July 23, 2004 when strong mesospheric echoes were observed by the MST radar at Gadanki. Ionosondes at SHAR and Thumba, MF spaced receiver drift radar at Tirunelveli and geomagnetic observatories at Tirunelveli and Alibag provided ground support. The Langmuir probe and MST radar data showed presence of small-scale irregularities in 75-77 km region. Detailed analyses are being made to examine the turbulence parameters from radar and rocket data. This work is done in collaboration with scientists from NMRF, ISRO HQ, SPL and IIG.

(H. Chandra, H.S.S. Sinha, R. N. Misra, S. R. Das, Uma Kota, M.B. Dadhania and S.B. Banerjee)

All Sky Imaging of Plasma Depletions Over Indian Zone during Solar Maximum

PRL's all sky imaging system was operated from Kavalur (12.56^{o} N; 78.8^{o} E) during February-April, 2002 to observe plasma depletions through 630.0, 557.7 and 777.4 nm airglow emissions. These observations showed the occurrence of plasma depletions continuously for several nights and for longer duration. Plasma depletions are observed in 557.7 nm only when the F region contribution of 557.7 nm dominates over the mesospheric contribution. These observations showed that in the pre-dawn hours plasma depletions are not seen in 777.4 nm images, while the 630 and 557.7 nm images showed strong and clear depletions.

(H.S.S. Sinha, P.K. Rajesh, S.B. Banerjee, R.N. Misra, N. Dutt, M.B. Dadhania, Uma Kota and J. Y. Liu)

Production of Hydrated Cluster Ions in the Laboratory

A number of laboratory experiments were conducted recently at the Institute of Space and Astronautical Sciences (ISAS) of the Japan Aerospace Exploration Agency (JAXA), wherein NO plasma was produced inside a big chamber by ionizing it by a very intense EUV source. Controlled amounts of water vapor and NO were introduced inside the chamber to simulate conditions similar to those in the D region of the Earth's ionosphere. It was found that the formation of ion clusters started within a minute but the time taken for various ions to come to their peak concentration varied (**Fig. 6.5**). Some of the new results obtained from these experiments are: (a) the detection of higher order clusters of proton and NO^{+} hydrates (102^{+}, 109^{+} and 127^{+})

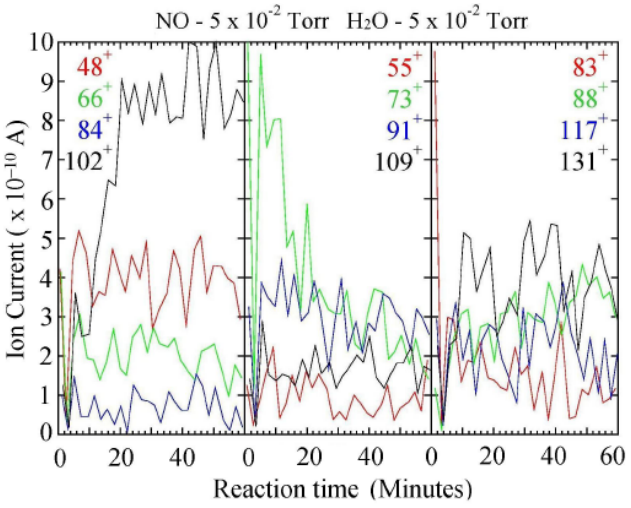


Fig. 6.5 : Temporal build-up of ions (a) $NO^+(H_2O)_n$ series, (b) $H_3O^+(H_2O)_n$ series and (c) of the other cluster ion series.

and (b) that the concentration of most of the hydrated ions showed oscillatory behavior. Detection of a number of ions was made in these experiments and a few new reaction paths have also been suggested based on these experiments. Effect of lower and upper thresholds of chamber pressure, for the production of cluster ions was observed. These pressure thresholds correspond to an altitude range of 50 to 100 km in the ionosphere. These experiments were done in collaboration with scientists of ISAS, JAXA, and Hokkaido University, Sapporo, Japan.

(H S S Sinha)

Geomagnetic Storms and their Ionospheric Effects

Geomagnetic storms that occurred during the period of 1997 to 2001, have been studied. The occurrence timing and the intensity of storm were highly correlated with the occurrence timing and intensity of the southward component of the interplanetary magnetic field. The storm-time effects in the ionospheric F2-region during the periods of 1989-1991 and 1999-2001 and VHF scintillations at Ahmedabad during 1999-2001 were also studied. The negative storm effects in f_0F_2 are more pronounced with a maximum occurrence in the post-midnight period. A decrease in f_0F_2, due to composition changes by the storm-induced circulation dominates over

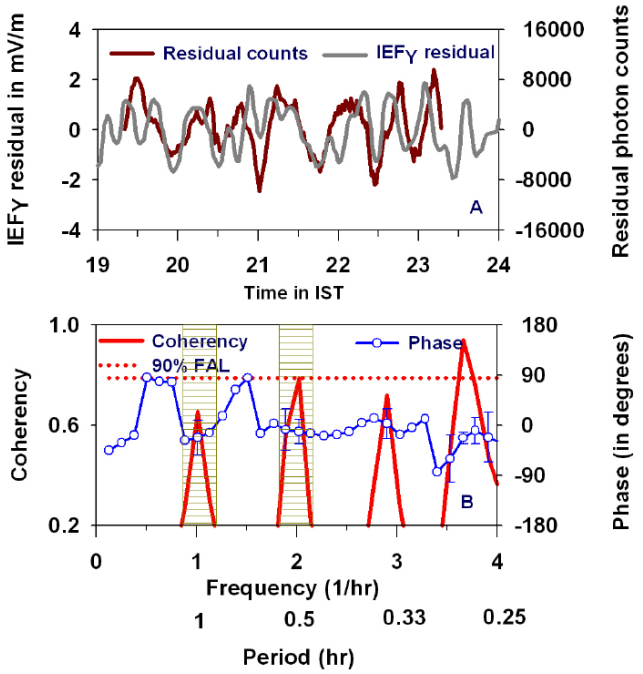


Fig. 6.6 : (A) Residual airglow intensity variations (red) and the time delayed (by the travel time from L1 to ionosphere) variations in IEFy (grey) on February 12, 2004, (B) corresponding coherency and phase spectra revealing two coherent periodic components (periodicities ~30 minutes and ~1.0 hour) with stable phase relationship. The two other frequency components are not considered owing to the absence of corresponding significant spectral peaks (not shown here) in the two given time series.

an increase in f_0F_2 due to an increase in h´F. This results in a net decrease in f_0F_2 in the post-midnight period. The probability of occurrence of scintillations in the post-midnight sector is enhanced for storms in which $D_{st} < 75$ nT. Magnetic storms with $D_{st} < 100$nT have been found to be most effective in producing such scintillations. Reversal of the equatorial ionospheric electric field due to the penetration of magnetospheric electric fields explains the occurrence of such scintillations. This work was done in collaboration with the University of Suva, Fiji.

(H. Chandra and Som Sharma)

Evidence of Interplanetary Electric Field Effect on OI 630.0 nm Nightglow over Low Latitude

On a geomagnetically disturbed and non-spread F night, small-scale, quasi-periodic fluctuations are ob-

served in the OI 630.0 nm nightglow intensity recorded from Gadanki. These small-scale intensity fluctuations are shown to vary in accordance with the equatorial electric field variations. More importantly, it is also evinced that the frequency components ~ 2 cycles/hr (period ~ 0.5hr) and 1cycle/hr (period ~ 1.0hr) in the airglow fluctuations have its origin in the Y component of the interplanetary electric field (IEFy) variations (**Fig. 6.6**). IEFy is calculated based on the magnetic field and solar wind velocity observations by the Advanced Composition Explorer (ACE) satellite located at the libration point L1 on the sun-earth line. It is also shown that these types of small-scale intensity fluctuations are absent on a geomagnetically quiet and non-spread F night. This investigation brings out the explicit signature of the solar wind electric field in the OI 630.0 nm airglow emission over low latitude. This work is done in collaboration with Space Physics Laboratory, VSSC and Indian Institute of Geomagnetism.

(D. Chakrabarty, R. Sekar, R. Narayanan, C. V. Devasia and B. M. Pathan)

Dependence of F Layer Movement on the Nocturnal Variations of 777.4 nm Airglow Intensity over Low Latitude

Co-ordinated optical and radar measurements have been conducted from Gadanki. Optical observations are obtained using a multi wavelength narrow band photometer whose field of view is chosen to coincide with the radar beam width. Airglow emissions at 630.0 nm and 777.4 nm emanating from bottom side of the F-region and from the peak altitude of the F-region respectively were monitored in a bi-directional mode (zenith and east) during these campaigns. The large scale intensity variations are observed on both the line emissions on almost all the nights while the small scale intensity variations, particularly in 630.0 nm, are observed either during ESF events or during geomagnetically disturbed periods. These observations bring out the similarities between the nocturnal intensity variations at 777.4 nm and 630.0 nm airglow on magnetically quiet nights when ESF events are not present, indicating that the 777.4 nm airglow emission is not completely independent of the F layer height movement, in contrast to the earlier belief. An investigation carried out in this regard reveals that the 777.4 nm airglow intensity variations depend on the F layer height variations in varying degrees. This work is done in collaboration with Space Physics Laboratory, VSSC.

(R. Sekar, D. Chakrabarty and R. Narayanan)

On the Electric Field Perturbations Associated with Geomagnetic Storm from the OI 630.0 nm Dayglow Observations from Mt. Abu

During a recurring storm event in February, 2002, the widths of the diurnal variations of the OI 630.0 nm dayglow intensity show a large day-to-day variability corresponding to the different phases of the storm. It is observed that the variations in the widths of the dayglow profile are different corresponding to the situations when the main phase of the storm is during mid-day hours and when the main phase is during mid-night hours. It is evident that the perturbation electric fields associated with the storm acted differently corresponding to the main phases of the storms occurring at the mid-day hours and mid-night hours.

(D. Chakrabarty, R. Sekar and R. Narayanan)

Laboratory Astrophysics

Recoil Ion Momentum Spectrometry

Recoil ion momentum spectroscopy of dissociative ionisation of CO_2 has been carried out at various electron energies. Momentum analysis of O^+ and CO^+ ions resulting from electron impact dissociative ionisation of CO_2 shows at least two distinct structures in the momentum spectrum (**Fig. 6.7**), suggesting two dissociation channels for simultaneous formation of O^+ and CO^+ from CO_2. Attempts are on, using theoretical inputs, to identify the electronic configuration of the excited electronic states leading to dissociation. Relatively high kinetic energy C^+ ions are identified. A rich structure in the momentum of the second partner in the C^+ dissociative ionisation channel has been observed but not yet understood. Complex molecules such as ethanol and

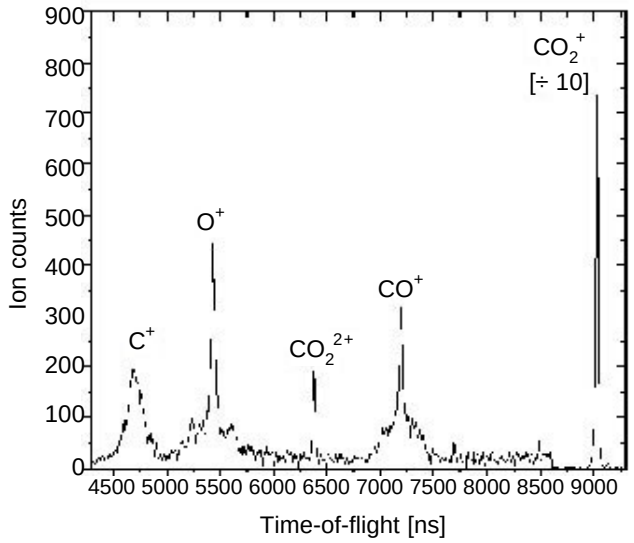


Fig. 6.7 : Time-of-flight spectrum of ions resulting from ionisation of CO_2. The width of the peaks is proportional to the momentum of the ions. Broad peaks of C^+, O^+ and CO^+ ions indicate large kinetic energy release during fragmentation.

methanol are also being studied, and a multitude of dissociation pathways is observed.

(Bhas Bapat and V. Sharma)

Characterization of Laser Produced Plasmas

With the new apparatus, for the measurement of spectra and evolution features of the laser produced plasma (LPP), time resolved spectroscopic measurements have been made on aluminium, copper and carbon plasmas. Excimer laser pulses are used to create plasma in a stainless steel vacuum chamber. The velocity of the plume is studied by time resolved measurements of emissions from laser produced plasma plume. Two shifted Maxwell Boltzmann (SMB) were required to fit the intensity versus time plot. This means that plasma consists of two population species each following a separate velocity distribution. It was further observed that for these components the instantaneous velocity when plotted as a function of distance exhibited a damped oscillatory behaviour. This shows that species of the plasma plume undergo accelerating and decelerating phases during the lifetime. Further, it was observed that even under very high vacuum conditions (10^{-5} mbar) the signal corresponding to wake was observed in contrast to the expectations.

In an experiment carried out at Institute of Plasma Research, ablation plume resulting from irradiation of carbon or lithium fluoride coated on a glass plate by pulsed nanosecond Nd-YAG (1064nm) in vacuum and at various pressures of argon is studied. The enhancement in the signal in optical channel with increase in pressure and the decrease in signal with increasing distance between target and field of view are the two important observations made so far.

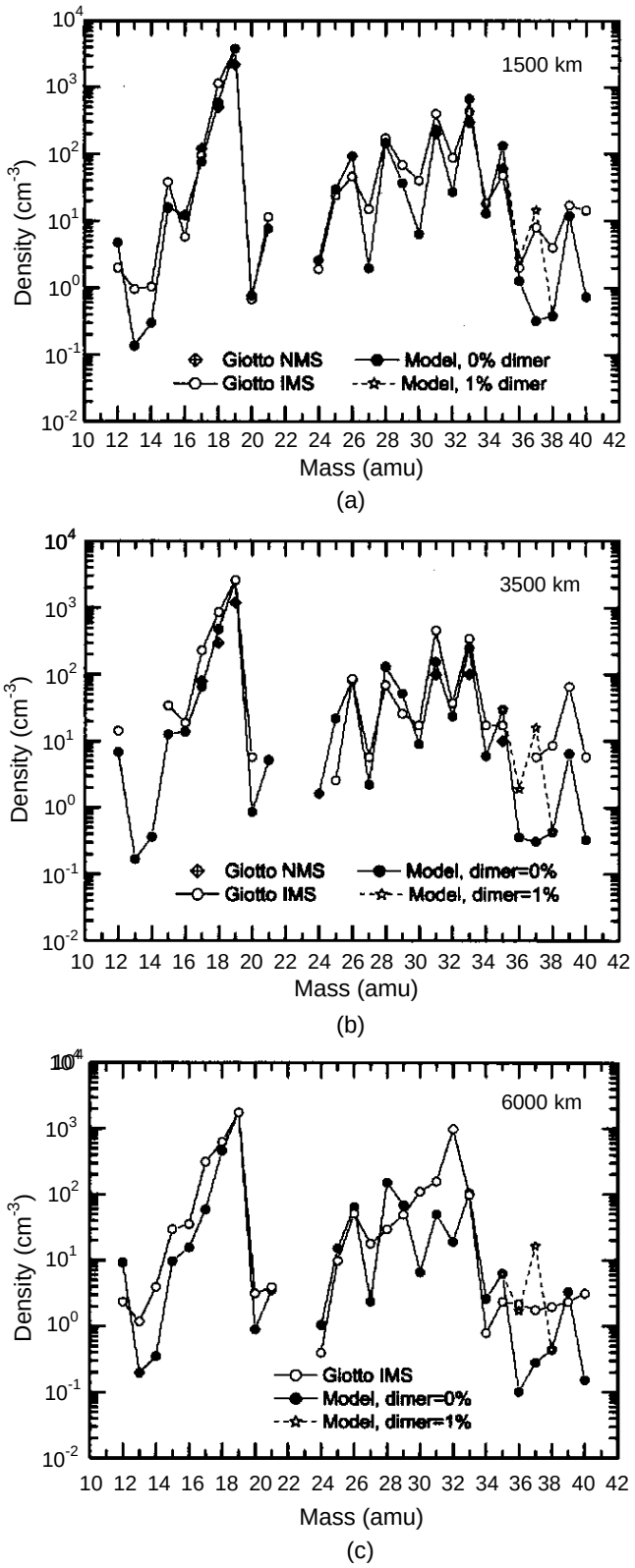
(K.P. Subramanian, I.A. Prajapati, B.G. Patel and R.K. Singh)

Planetary and Cometary Atmospheres

Longitudinal Variability in Martian Ionosphere

Mars Global Surveyor (MGS) has observed thermospheric and ionospheric densities in the dayside ionosphere of Mars at high latitude under solar medium condition. The preliminary analysis of these measurements suggests that Martian thermosphere/ionosphere is controlled by strong tidal waves at low altitude region. These measurements were carried out in December, 1998 for solstice Ls = 74 - 77 at northern latitude from 64.7 to 67.3^o N between solar zenith angle $78\text{-}81^o$. We have calculated longitudinal distribution of production rates, ion density and electron density in the dayside ionosphere of Mars. These calculations are made at solar zenith angle 80^o between latitudes 50^o and 70^o N for spring equinox and medium solar activity condition. At about all longitudes these measurements represent primary and secondary ionization peaks, which were produced by photoionization and photoelectron impact ionization processes corresponding to solar radiation of wavelength range 9-102.5 nm and 1-9 nm respectively. There is good agreement in general with observations except that the calculated peak heights of primary/secondary ionizations are more than the measurement by a factor of 1.5.

(S.A. Haider, V.R. Choksi and S.P. Seth)



Chemistry and Composition of Comets

The chemistry and composition of the coma of a comet is not fully understood. The present study involves the theoretical investigation of the chemistry of the coma of comet Halley, which will characterize the chemical and physical properties of the nucleus by fitting a model calculation to the observation. The primary ionization source in the model is solar EUV photons, photoelectrons and auroral electrons of solar wind origin. It is found that at radial distances greater than ~1000km (±500 km) the major chemical processes that govern the production and loss of several of the important ions in the inner coma are different from those that dominate at distances below this value. The importance of photoelectron impact ionization and the relative contributions of solar EUV and auroral and photoelectron ionization sources in the inner coma are clearly revealed by the present study. The calculated ion mass densities are compared with Giotto Ion Mass Spectrometer and Neutral Mass Spectrometer data at radial distances 1500 km, 3500 km and 6000 km (**Figs. 6.8 a, b and c**). There is a reasonable agreement between model calculation and Giotto measurements. The nine major peaks in the measurement between masses 10 and 40 amu are produced fairly well by model within factor of two inside the ionopause.

(S.A. Haider and A. Bhardwaj)

Fig. 6.8 : (a) Ion density spectra for masses 12-40 amu at radial distance 1500km. The Giotto IMS data are also presented in this figure. The model calculations are presented without and with 1% dimer cases. (b) Same as shown in (a), but at radial distance of 3500km. (c) Same as shown in (a), but at a radial distance of 6000km. In this figure, only the Giotto IMS data are shown..

The research activities of the division have mainly focused on delineating processes and time scales related to early solar system, planet mars and earth's lithosphere, hydrosphere, biosphere and atmosphere. Some selected activities including a new dating technique developed have been described here.

^{26}Al Records in Chondrules and the Role of Thermal Metamorphism

Continuing study of ^{26}Al records in chondrules from a set of unequilibrated meteorites reinforces the suggestion for a late formation of chondrules as well as extended duration of chondrule formation. So far studies of chondrules from four unequilibrated chondrites, LEW 86134,7, belonging to the lowest metamorphic group (3.0), and Adrar-003, ALHA77176 and QUE97008 belonging to higher metamorphic groups (3.2 and 3.4) have been completed. The highest value for initial ^{26}Al/^{27}Al in chondrules inferred from the data is at least a factor of three lower than those normally seen in CAIs. Further, the data are also indicative of differential thermal history experienced by chondrules from individual meteorite indicating the possibility that pre-parent body episodes of thermal metamorphism may have affected some of these chondrules.

(R Gowda, M. P. Deomurari and J. N. Goswami)

Cosmic Ray Exposure Records and Trapped Gases in the Martian Meteorite MIL 03346

Samples from martian meteorite MIL 03346, the seventh nakhalite have been analysed for nuclear tracks and noble gas components to delineate the cosmic ray exposure history of this meteorite and signatures of martian atmospheric and interior components in it. The exposure age of 9.6 ± 1.0 Ma is similar to those of other nakhlites, supporting a single ejection event for all the known nakhlites. Nuclear track production rate indicates a pre-atmospheric radius of ~ 6 cm and mass ablation of ≤ 75% for MIL 03346. ^{129}Xe/^{132}Xe ratios in all temperature steps are in the range 1.75-2.32 and clearly suggest the presence of martian atmospheric component. The trapped ratios ^{84}Kr/^{132}Xe (0.66) and ^{36}Ar/^{132}Xe (6.1) are much lower than the fractionated martian atmospheric values generally found in nakhlites. In a plot of ^{129}Xe/^{132}Xe versus elemental ratio ^{84}Kr/^{132}Xe (**Fig. 7.1)**, the data points of MIL 03346 fall further to the left than other nakhlites, suggesting a more severe elemental fractionation than hitherto observed in nakhlites. Surficial adsorption on sediments, and assimilation of such sediments into the magma seems to be the most plausible mechanism that can explain this fractionation.

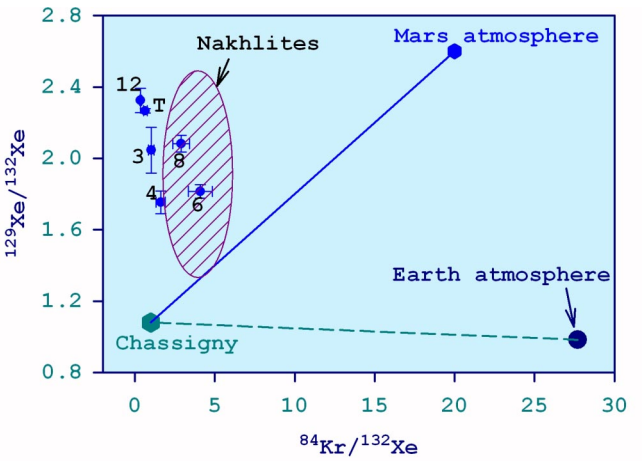


Fig. 7.1 : Plot of ^{129}Xe/^{132}Xe vs ^{84}Kr/^{132}Xe for different temperature fractions of MIL03346. Number beside the point indicates temperature in 100' s of ^{o}C. Most data points fall outside the range of nakhlites.

(S.V.S. Murty, R.R. Mahajan, J.N. Goswami and N. Sinha)

Studies of Recent Meteorite Falls over India

Two meteorites, the Kasauli meteorite that fell in northern India and the Kendrapara meteorite that fell over coastal region of Orissa in 2003 (**Fig. 7.2**) were studied for petrographic characteristics and chemical composition. Results suggest that the two meteorites belong to the H group of chondrites with Kasuali suffering a lesser degree of thermal metamorphism than Kendrapara during their residence in their parent bodies. Cosmogenic records indicate a large size for the Kendrapara meteoroid that has spent ~5 million years in interplanetary space following its ejection from its parent body until its fall on earth. On the other hand, the Kasauli meteoroid spent an unusually long time (~37 Ma) in interplanetary

Fig. 7.2 : Fragment of Kendrapara meteorite (top); The Kasauli meteorite (bottom)

space before its fall and lost ~ 80% of its original mass during atmospheric ablation. This work was carried out in collaboration with Geological Survey of India, Kolkata.

(J.P. Das, A. D. Shukla, R.R. Mahajan, P. N. Shukla, S. V.S. Murty, N. Sinha and J. N. Goswami)

U, Th-^{21}Ne Dating : A New Thermochronometer

It is demonstrated for the first time that the nucleogenic noble gas isotope,^{21}Ne, produced by (α, n) reactions on ^{18}O in U, Th rich materials can be used to date apatite in carbonatite by analysing such samples from Hogenakal, South India. Previous age determinations, on the same suite of samples, by Sm-Nd whole rock-mineral isochron method yielded an age of 2400 Ma and by Rb-Sr mica-whole rock isochron resulted in a thermal reset age of 1.9 Ga. Using nucleogenic ^{21}Ne we derive a noble gas retention age of 845 ± 127 Ma for the apatite in carbonatite from Hogenakal. This age is considerably younger than the thermally reset Rb-Sr mica age but is in good agreement with the younger 770 Ma carbonatite - syenite - alkali granite emplacement event in the region. This system, therefore, has the potential to identify low temperature metamorphic events and to estimate cooling histories of large igneous complexes.

(S. Basu, S.V.S. Murty and Anil Kumar)

Evolution of the Dharwar Craton, Southern India

The Dharwar craton comprising of the western and the eastern block, with the eastern margin of Chitradurga schist belt acting as a notional boundary between them, forms a major part of the southern Indian shield. Extensive studies of samples of metasediments (quartzites and metapelites) and gneisses and gneissic enclave from the eastern Dharwar block reveal widespread presence of older sialic crust in this region with zircon ages of 3.1 to 3.3 Ga calling into question the earlier suggestions regarding the evolution of the eastern block and its amalgamation with the western block. The data clearly suggest the existence of older archean crust in this region that was perhaps been reworked by large scale granitic emplacement during the early proterozoic and also later granulite metamorphic event that affected this region.

(B. Maibam, M.P. Deomurari, J.N. Goswami and R. Srinivasan)

Noble Gases and Nitrogen in Lonar Impact Glasses

Lonar is the only known impact site on the Earth in basaltic terrain and occurs within the Deccan Trap basalts. Presence of both impact glasses as well as high silica tektite-like glasses have been reported from Lonar. Though trapped gases in these samples are expected to be of atmospheric composition, one might expect to find remnants of gases from the target material and in exceptional cases signatures of the impactor. Noble gases and N signatures of Lonar impact glasses have been studied by vacuum crushing to look for remnant volatile signature. Vacuum crushing lead to release of gases trapped in vesicles, with minimum contribution from in situ produced (mostly radiogenic) gases. The results indicate that the impact glasses are rich in all noble gases and N as compared to the tektite-like ones. The N (ppb) and ^{36}Ar (10^{-10} ccSTP/g) are respectively

287 and 33.4 for tektite-like glasses, and 1536 and 172.3 for the impact glasses. The depletion indicates that the tektite-like glasses were subjected to higher temperature during formation and/or have lower vesicularity. The noble gas isotopic ratios are close to atmospheric for both types of glasses. It wsa observed enrichments (relative to air) of ^{4}He and ^{40}Ar, which can not be explained as in situ radiogenic components, considering the facts that only a small fraction of radiogenic gases from matrix can be released during vacuum crushing and the young age of Lonar Crater ($\leq$ 50 Ka) and its U, Th and K contents. These radiogenic ^{4}He and ^{40}Ar excesses are a remnant from the target rocks, the Deccan Trap basalts. Non-atmospheric δ^{15}N signatures (-2 to -8‰) further support the presence of remnant source rock gases in the Lonar Crater glasses.

(S.R. Managave, S. Basu and S.V.S. Murty)

Helium, Radon, and Radiocarbon Studies on a Regional Aquifer System of North Gujarat – Cambay Region, India

The age evolution of groundwater as it flows from the recharge area through a regional alluvial aquifer system in North Gujarat - Cambay Region in western India was studied. ^{14}C, ^{4}He and ^{4}He/^{222}Rn dating methods were employed. Sediments from a drill core in the Cambay Basin were also analysed for U and Th concentrations and the measured values were used to estimate the ^{4}He and ^{222}Rn production rate for groundwater age calculations. Additionally, factors controlling the distribution of ^{222}Rn, ^{4}He and temperature anomalies in groundwater, vis-à-vis their relation to the tectonic framework and lithology of the study area, were also examined. The ^{14}C ages increased progressively in the groundwater flow direction, from the foothills of Aravalli Mountains in the east, and reached a value of ~ 35 ka towards the region of lowest elevation, linking Little Rann of Kachchh (LRK) - Nalsarovar (NS) - Gulf of Khambhat (GK) in the western part of the study area. In this region, groundwater ages obtained for free flowing thermal wells and springs employing ^{4}He and ^{4}He/^{222}Rn systematics are of the order of million years. Such anomalous ages are possibly due to enhanced mobilisation and migration of 'excess helium' from hydrothermal circulation vents along deep-seated faults. The estimated ^{4}He and ^{4}He/^{222}Rn groundwater ages are in reasonable agreement with ^{14}C age estimates in the Cambay Basin. The ^{4}He method also indicated west-southwards progression of groundwater ages up to ~ 100 ka beyond the Cambay Basin.

(Meetu Agarwal, S.K. Gupta, R.D. Deshpande and M.G. Yadava)

Seasonal Variation in Oxygen Isotope Ratio of Selected Indian Rivers : Signature of Source Waters

Temporal variation of isotopic ratios in river waters may be useful in tracing the magnitude of recent climate change induced by increase in greenhouse effect. During the last two years, Studies have been carried out of oxygen isotopic variations on a set of Indian rivers: Ganga (main canal at Dhanauri), Yamuna (main canal at Saharanpur), Beas and its tributary Parbati (near Bhuntar, Kullu), Tista (at Jalpaiguri), Hooghly (near Burdwan) and Narmada (near Garudeshwar, Gujarat). The first six are Himalayan rivers and the last one is a central Indian river from Vindhyan Hills.

Oxygen isotope ratios were measured in collected samples (weekly or bimonthly) from early 2002 and data have been obtained for about 100 samples in each case. The time variation plots reveal effects of snow melt contribution to integrated rain water capture and evaporation during transport.The average δ^{18}O (‰) values (number of samples) are: Ganga –9.3 ± 0.8 (83); Yamuna – 7.9 ± 0.8 (84); Beas – 9.1 ± 0.6 (70); Parbati –10.2 ± 0.9 (71); Tista – 7.7 ± 1.4 (98); Hooghly – 6.9 ± 0.98; Narmada – 3.9 ± 1.2 (100). All the six Himalayan rivers have lower mean δ^{18}O (– 8 to –10 ‰) compared to the peninsular river (Narmada). The Himalayan Rivers have substantial contribution from rain systems at the end of the Monsoon track resulting in depleted ^{18}O. Also, in some cases (like Bhagirathi or Alaknanda for Ganga) high altitude glaciers contribute melt waters, which are highly depleted. The variation of ~ 2 ‰ among them can also be explained by melt-water contribution. It is seen that the lowest δ^{18}O values for these rivers are obtained

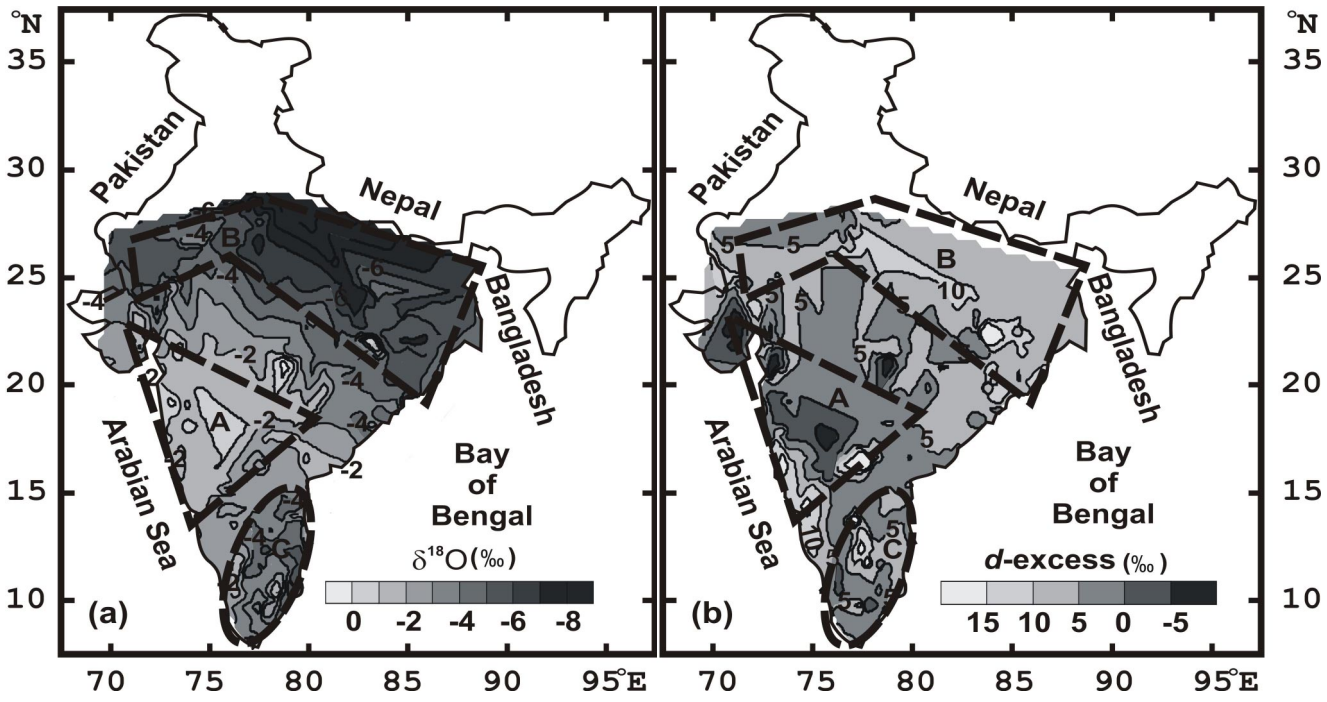


Fig. 7.3 : Spatial distribution of (a) of $\delta^{18}O$ and (b) d-excess in groundwater samples based on compilation of isotopic measurements. At most stations only one measurement is available. For groundwater sources having multiple measurements (<1%) an average value has been used. Based on $\delta^{18}O$ distribution, the country can be broadly subdivided into three contiguous Regions A, B and C with transition areas in between.

during the months of August and September i.e. the post monsoon period. This is probably caused by high intensity rains coupled with snowmelt contribution.

(S.K. Bhattacharya and R.A. Jani)

Factors Controlling the Stable Isotope Distribution in Ground Waters of India

Available data of isotopic measurements of shallow unconfined groundwater samples from different parts of the country and measured by different laboratories were compiled and distribution of $\delta^{18}O$ and d-excess parameters (**Fig. 7.3a, b**) was studied in relation to (i) sources of primary precipitation and its isotopic composition; (ii) physiographic features; (iii) annual precipitation amount; (iv) annual mean potential evapotranspiration; and (v) surface soils. Based on $\delta^{18}O$ distributions of groundwater, the country can be broadly subdivided into three contiguous Regions A ($\delta^{18}O > -2$ ‰), B ($\delta^{18}O <$ -4 ‰) and C ($\delta^{18}O$ around -3 ‰ to - 4 ‰) with transition areas in between (Fig. 3a,b).

In coastal parts of the Region A, dominated by heavy rainfall from the Arabian Sea branch of the SW monsoon, ground waters largely reflect isotopic characters of the rainfall. But on the rain shadow side of the Western Ghats, with high PET (Potential Evapo-Traspiration) and low permeability black soil, signatures of significant pre-recharge evaporative enrichment of heavy isotopes are evident. In contrast, the groundwater in Region B largely retains the isotope character of precipitation acquired from the Bay of Bengal Branch of the SW monsoon. This is facilitated by a combination of factors such as relatively larger rainfall, lower PET, more permeable soil cover and selection effect, particularly in the desertic areas. In the Region C, with a dual monsoon system, ground waters in coastal areas retain isotopic signatures of Arabian Sea branch of the SW monsoon on the west coast and of NE winter monsoon on

the east coast. In the interior areas, high PET and low permeability soil cover lead to evaporative enrichment of heavy isotopes except on Eastern Hills.

(S.K. Gupta and R.D. Deshpande)

Rain-aerosol Coupling over Ahmedabad : Scavenging Ratios of Chemical Species

The abundances of chemical species in individual rain events are governed by scavenging from the aerosol and/or gas phase, either incorporated directly in the clouds (in-cloud scavenging) or wash-out by the precipitation (below-cloud scavenging). In the latter process, concentration of a species is not only dictated by precipitation amount but also by its "scavenging efficiency", defined as the dimensionless "Scavenging Ratio" (SR), of the concentrations measured in rain with respect to those in the aerosols. The long-term study of aerosols and individual precipitation events over Ahmedabad has provided representative SRs of selected chemical species (NH_4^+, Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^- and $SO_4^=$) for an urban site of a semi-arid region. The total dissolved solids (TDS) in rain events varied from 1.9 to 137 mg l^{-1} and are shown to vary with the precipitation amount (**Fig. 7.4a**). This is interpreted as a dilution effect related to the depletion of the aerosol source. The order of SRs is shown in **Fig. 7.4b**. The rain events with highest SRs for individual species are characterized by low precipitation amount. The inter-species variations in the SRs (Fig. 7.4b) mainly reflect the differences in the partitioning of the constituents between the gas and particulate phase. Hence the largest SRs are associated with NH_4^+ and NO_3, as the occurrence of these species in the rain is dominated by gas phase scavenging. The SRs provide a potential tool for investigating the mechanism of transfer between aerosols and precipitation and more importantly for predicting the chemical concentration in rain events.

(N. Rastogi and M.M. Sarin)

Chemical Uptake of Acidic Species by Mineral Aerosols over a Semi-arid Region

A long-term study carried out at a sampling site in Ahmedabad has documented important in-situ chemical reactions involving uptake of acidic species ($SO_4^=$ and NO_3^-) by mineral aerosols. During the drier months (Jan-Apr, Sept-Dec), atmospheric abundances of μgm^{-3}anthropogenic $SO_4^=$ and NO_3^- exhibit large variability over Ahmedabad; $SO_4^=$: 2.6-7.7, ; NO_3^- : 0.4-4.0,. Excess acid (EA) = (NO_3^- + $SO_4^=$) – (NH_4^+ + K^+). It is implicit in this approach that fraction of acid is neutralized by NH_4^+ and K^+. The uptake of EA is gauged by the extent of HCO_3^- removed (defined as Ca^{2+} minus HCO_3^-) from mineral aerosols during in-situ chemical reactions. This is evident from the inverse relationship observed between decrease in HCO_3^-/Ca^{2+} ratio with increase in EA/Ca^{2+}. It is estimated that percentage of EA

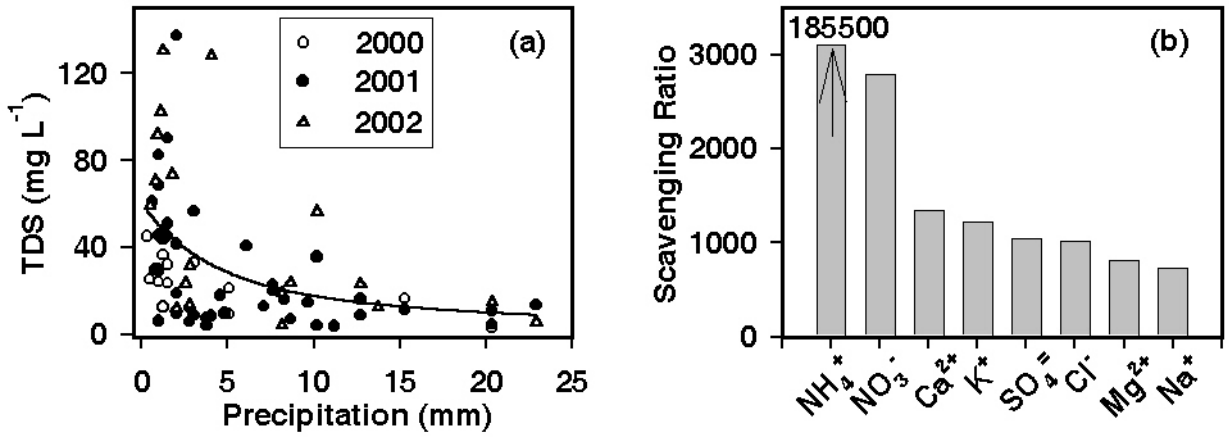


Fig. 7.4 : (a) Variation in Total Dissolved Solids (TDS) with increasing precipitation volume for individual rain events (n = 72) during the period of SW-monsoon. (b) Geometric mean of Scavenging Ratios (SRs) of chemical species over Ahmedabad.

uptake by mineral aerosols varies from 40 to 100% of the total EA. Such chemical processes could change the size distribution of sulphate and nitrate aerosols from fine to coarse mode as well as surface property of mineral aerosols from hydrophobic to hydrophilic; this in turn could increase the efficiency of mineral dust to act as cloud condensing nuclei.

(N. Rastogi and M.M. Sarin)

Chemical Characteristics of Aerosols during ISRO-GBP Land Campaign

Chemical characteristics of ambient aerosols over spatially separated locations along the highway from Ahmedabad to Hyderabad (covering a lateral distance of ~1200 km) were studied during the ISRO-GBP land campaign, February 7-29, 2004. Bulk-aerosol samples were collected (near the surface) onto tissuquartz filters (200 x 250 mm^2) using a high-volume sampler and analyzed for a suite of chemical constituents. In addition, aerosol samples were collected on February 19-20, over Hyderabad at three different altitudes (600, 1300 and 2250 m) using NRSA's Beachcraft 20 aircraft. In near surface, aerosol mass loading ranged between 34 to 208 μgm^{-3}; relatively enhanced aerosol concentrations were observed along the sampling track in Gujarat region. The most conspicuous differences in the aerosol characteristics were in the anthropogenic constituents ($SO_4^=/NO_3^-$); significantly higher ratios (~8-9) occurring in and around Hyderabad influenced by vehicular emissions. In addition, aerosol $SO_4^=/NO_3^-$ ratio varied strongly from 13 to 22 as a function of altitude, suggesting the predominance of NO_3^- from biogenic and dust sources; whereas elevated $SO_4^=$ abundances result from anthropogenic sources.

(R. Rengarajan, M.M. Sarin and A.K. Sudheer)

Dating of Fulgurites : A New Paleo-environemental Tool

Lightning striking the earths surface fuses the grains in sandy deposits producing glassy-rods, known as fulgurites. Fulgurites form in-situ and are commonly found in deserts. It is demonstrated that fulgurites could be dated using thermo-luminescence technique and, that the trapped gases in fulgurites can provide clues to contemporary environmental conditions. Detailed SEM-Cathodoluminescence - EDAX studies enabled characterization of the luminescence mineralogy and the development of a suitable dating protocol that yielded an age of 15 ka, for a fulgurite from Sahara-Sahel boundary. Trapped gases by laser ablation gas chromatography-mass-spectrometry indicated that about 1.3 ± 0.7 % of this fulgurites mass was due to CO_2, CO and NO and C/N ~ 0.15, similar to that in soils with organic matter in the present day Sahara-Sahel boundary region about 1000 km south. This suggests that the fulgurites formed during humid temperate climate in contrast to its present day occurrence in a hyper-arid desert. the studies, therefore, enable a direct documentation of the paleolimits of Sahara-Sahel boundary with implication on albedo changes during the past.

(A.K.Singhvi, R.N.Gonzalez and S.Mahan)

Luminescence and ESR Dating of Gypsum from Thar Desert and New Mexico

Gypsum is an important climatic marker in dryland studies. However, it has not been possible to date this directly. During the past year we successfully attempted a direct and indirect dating of gypsum using Optical and Electron spin resonance (ESR) dating methods. The direct method involved dating of associated quartz in the case of wind transported gypsum sands or ESR dating of gypsum itself. The indirect method involved dating of the sediment layers above and below the gypsum horizon. Both the approaches were successful and ages in the range from few hundred years to 7ka were obtained from the white sands in New Mexico, USA and from 10 ka to 1 ka in the case of Thar Desert. Currently detailed investigations towards characterizing gypsum using DTA (Differential Thermal Analysis), DTG (Differential Thermal Gravity), FT-IR (fourier Transform Infrared) and ESR are underway and the results so far show that both the chronology and the pathways in the formation of gypsum can also be understood. This will be a major new advance in arid zone paleoclimatology.

(N. Juyal, Y.C. Nagar, M.D. Sastry, A.K. Singhvi, S.K. Wadhawan, G. Kocurek, K.P. Mishra, Brij Bhushan, Amit, S., M.D. Deo and A. Sastry)

Paleoenvironmental Record of the Gran Desierto Sand Sea, New Mexico

The Gran Desierto Sand Sea of Sonora, Mexico, is located on the northeastern shore of the Gulf of California, east of the Colorado River Delta. The modern sand sea covers an area of 5700 km² and is the largest active dune field in North America. Individual generations of dune geomorphic features were identified and 'backstripped' using Landsat images and statistical analysis of physical parameters of the dune forms. Aeolian sand units overlie alluvium that was optically dated to ~87 ka to ~26 ka. Six generations of dune geomorphic features ranging in age from 26 ka to modern were identified above these units. Wind regimes since the Last Glacial Maximum were reconstructed based on the concept of gross bedform normal transport. From ~26 ka to ~12 ka, winds shifted from N and NNW to NW and S. From ~12 ka to ~ 10 ka, winds shifted to a dominant SE component with a subordinate NW component. From ~10 ka to ~6 ka, NW winds became dominant over the south winds. Modern conditions were reached by (at latest) ~6 ka, with the exception of enhanced ENSO cycles ~2.4-2.8. This is the first rigorous reconstruction of winds for this sand sea.

(P. Morthekai, A.K. Singhvi, G. Kocurek, N. Lancaster and S. Mahan)

Paleoenvironment from Humid Regions

Himalaya

Loess and intercalated soil horizons in the southwest monsoon dominated Central Himalaya were reported for the first time and a detailed investigation based on field stratigraphy, geochemistry, mineral magnetism, Infrared Stimulated Luminescence (IRSL) and radiocarbon dating enabled identification of three loess accretion events. The first two events of loess deposition occurred during 20 ka to 9 ka and were separated by a phase of moderate weathering. At the end of this phase, a well-developed soil formed during 9 ka to > 4 ka. This was followed by the third loess accretion event around 4 ka to > 1 ka. The present study suggests weak southwest monsoon between 20 ka to > 15 ka, 12 ka to > 9 ka and 4 ka to > 1 ka and enhanced southwest monsoon between ~16 ka to 12 ka. The period during 9 and > 4 ka experienced intense monsoon conditions.

(N. Juyal, A. K. Singhvi, M. G. Yadava, R. K. Pant, N.Basavaiah, N.K.Saini and E. Appel)

Central India

A detailed stratigraphic and optical dating studies in the Son and Belan river basin were carried out. The results suggest that the north-central Indian rivers have experienced a varied aggradation history during the past 100 ka. The earliest phase was of a local alluvial fan and debris flow event that ceased with the emplacement of an aeolian dust mantle towards 100 ka. The other aggradation events were at ~ 71 ka, 58 to 45 ka and ~39 to ~15 ka. The interval from 39 - 15ka was associated with the most widespread and prolonged aggradation. The aggradation ended with sustained vertical incision at ~ 15 ka suggesting a relatively sudden return to warmer and wetter conditions and a stronger summer monsoon. During the Holocene, the youngest phase of aggradation began towards ~ 5.5 ka suggesting a return to a more variable summer monsoon regime associated with more frequent El Niño-Southern Oscillation (ENSO) events.

(M. Jaiswal, A.K. Singhvi, M.A.J. Williams and J.N. Pal)

Weathering and Erosion in the Deccan

As a part of the ongoing investigation on weathering of Deccan Traps, bank sediments from many rivers of the Krishna system and the west flowing Western Ghat rivers have been analysed for their major and minor elemental abundances and Sr isotopes. The goal is to assess the mobility of various elements during chemical weathering and compare the results with dissolved phase.

The abundances of Na (av.= 0.62 wt.%), Ca (av.= 2.52 wt.%) and Mg (av.= 1.8 wt.%) in all the samples analysed are less than that in basalts. Similarly, Sr in samples with $CaCO_3$ < 0.5 wt.% is also less than that in basalts. These results coupled with their strong inverse correlation with Al suggest that Na, Ca, Mg and Sr are highly mobile from basalts during weathering. The

Ca/Mg and Na/Mg and Sr/Mg ratios in basalts, in sediments and in river waters draining them all are nearly the same, indicating that these elements are released from Deccan basalts to rivers nearly congruently. K does not show significant mobility from basalts and does not correlate well with other mobile elements. Ba shows a good correlation with K suggesting their similar behaviour and association in common phases such as felspars, clays and Fe-(oxy)hydroxides. The abundances of Al, Fe and Ti show significant variations, the average concentrations however, are higher than those in basalts attesting to their resistance to weathering. The strong correlation of Fe and Ti suggests the presence of weathering resistant Fe-Ti minerals (e.g. Titanomagentite and/or ilmenite). Our study highlights the convergence in conclusions arrived at on the mobility of elements from the study of two complementary phases - the dissolved and the sediments; though, different time domains are associated with these two phases.

(A. Das and S. Krishnaswami)

In addition to the Krishna river system the Chambal river system was also studied for their Sr isotopes as this river basin has a significant Deccan Trap component. The dissolved Sr ranges from 1.86 to 5.85μM with ^{87}Sr / ^{86}Sr, 0.70923 to 0.71222. Higher ^{87}Sr / ^{86}Sr of Chambal can be ascribed to the weathering of the Vindhyan sediments.

(R. Rengarajan and Sunil K. Singh)

Ganga Sediments

A comprehenssive study of the chemical and isotopic (Sr & Nd) composition of sediments of the Ganga River System has been initiated to trace their sources and determine the spatial variabilty in the erosion rates over the central and western Himalaya. Towards this, sediment samples collected from the Ganga at its origin, Gangotri, in the Higher Himalaya, to its mouth near the Farakka dam in the plains, and from many of its tributaries were analysed for their Sr and Nd abundances and ^{87}Sr / ^{86}Sr and ε_{Nd} at PRL with the newly installed TIMS. ^{87}Sr / ^{86}Sr varies from 0.74739 to 0.84279 with Sr in the range of 37 to 119 μg g^{-1}. ε_{Nd} also displays significant variation from -25 to -15 with Nd concentration of 10 to 35 μg g^{-1}. The $^{87}Sr/^{86}Sr$ and ε_{Nd} of the Ganga shows that they decrease from 0.78652 and -18 at the foothills to 0.75772 and -19 at Barauni which marginally increases to 0.76354 and -18 at Rajmahal due to the confluence of the Kosi with ^{87}Sr / ^{86}Sr and ε_{Nd} 0.80183 and -18.5 respectively. Preliminary results of material balance calculations using Sr, Nd, ^{87}Sr / ^{86}Sr and ε_{Nd} show that the Gandak is the dominant supplier of sediments to the Ganga at its outflow.

(Santosh K. Rai and Sunil K. Singh)

High-resolution Paleomonsoon from Cave Deposits

A speleothem (cave deposit) collected from the Sota cave in the Chitrakoot district of Uttar Pradesh was analyzed for stable isotopes of oxygen and dated by the radiocarbon method. Within the time span covered by the sample (~2800 yr BP), the amplitude of $\delta^{18}O$ changes is very large (> 2‰) and, therefore, cannot be explained by past variations in air temperature alone. We show that changes in past rainfall should have been the prime factor responsible for large variations in the speleothem $\delta^{18}O$. Rainfall in the cave locality has been reconstructed for the last ~2800 y. The average rainfall has an increasing trend with a periodicity of about ~1ky. We have compared the past rainfall of the Sota cave with similar reconstructions available from Gupteswar and Dandak caves and find that there are similarities and the extremely low rainfall events around 2000 and 1700y BP are also seen in the new record. Low rainfall years in the reconstruction are associated with similar events observed in the instrumental and historical records. The most depleted $\delta^{18}O$ that occurred ~100 yr ago may have been due to deficient rainfall years during A.D. 1877 to 1883.

(R. Ramesh and M.G. Yadava)

Evidence of Early Human Occupation in the Limestone Caves of Bastar, Chhattisgarh

Kotamsar and Dandak caves are one of the cave complexes located in the densely forested hilly area in Kanger Valley National Park, Bastar district, Chhattisgarh. Kotamasar cave is around 330 m in lat-

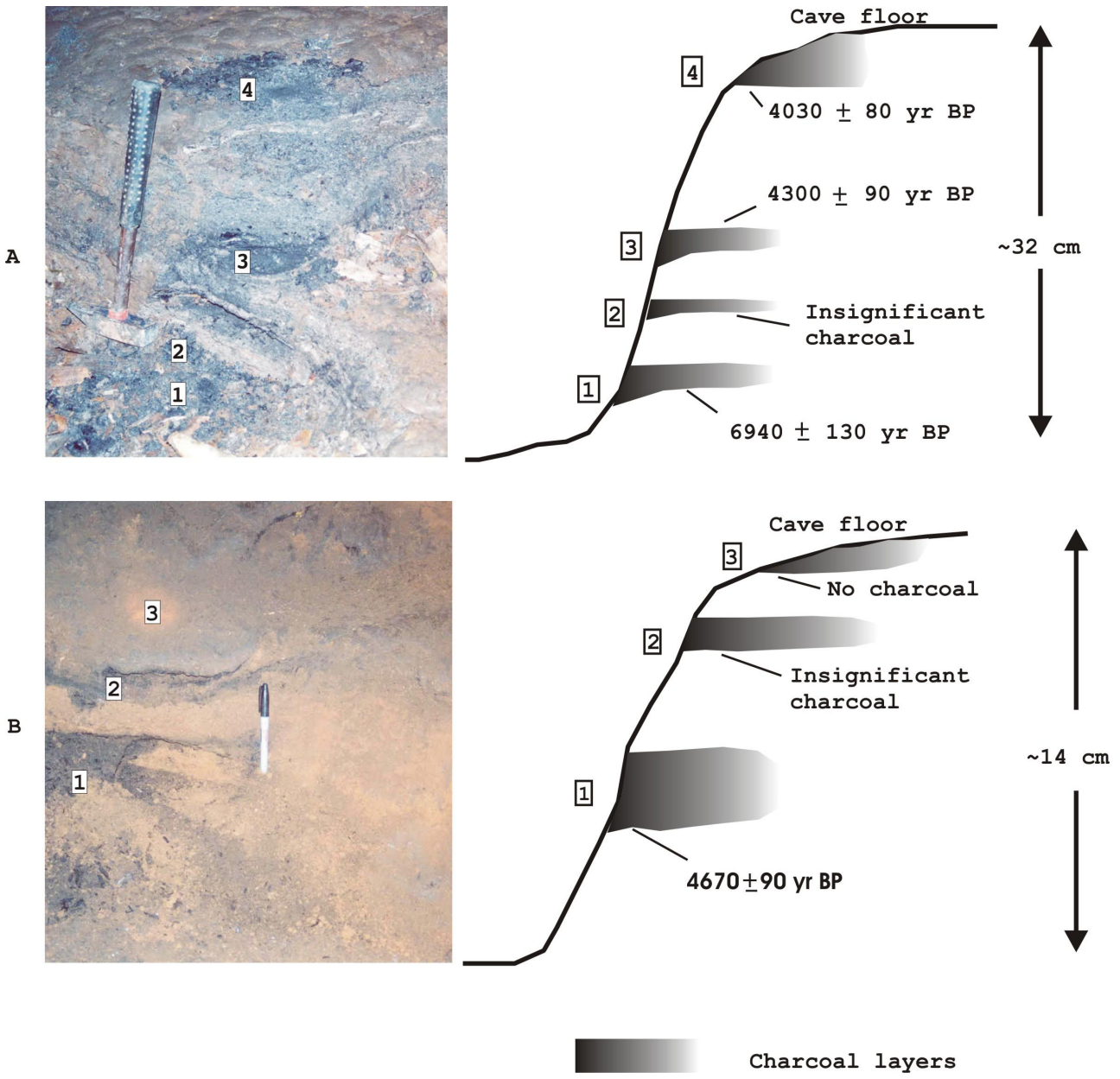


Fig. 7.5 : Charcoal layers inside the cave sediments (A) Kotamasar, numbers 1 to 4 and (B) Dandak, numbers 1 to 3.

eral extent with several well-developed chambers and the passages, up to 20-70m wide. The Dandak cave is located within ~ 5km distance from Kotamsar and has a lateral extent of about 200 m; the passages are 15 - 20 m wide. We came across evidences of controlled fire that was preserved as burnt earth, patches of charcoal mixed with soil and grasses suggesting human occupation in the dark galleries of these caves (**Fig. 7.5**). Radiocarbon dating was carried out on these charcoal layers suggesting that these caves were dwelling sites for prehistoric man during 4030 to 6940 yBP. Palaeobotanical studies show grains of three grass species and two complete seeds of a dicotyledonous herb. Presence of grains and seeds at 7 ka BP indicates domestication of plants and initiation of agricultural activity by the prehistoric man in the region. It appears that the

people who occupied these caves were probably of Mesolithic to Neolithic period and extended well into the mature Harappan times. These caves were abandoned around 4 ka, probably due to the increased aridity in the area. This is the first reporting of the Human evidences in the limestone caves of Bastar.

(R. Ramesh, M.G. Yadava, K.S. Saraswath and I. B. Singh)

Mass Independent Isotopic Fractionation in CO_2 Produced from $O(^3P)$+CO Reaction

Almost all oxygen reservoirs known, have oxygen isotopes that are fractionated in such a way that change in ^{17}O / ^{16}O from normal value is always about half of that ^{18}O /^{16}O. An exception to this rule occurs in stratospheric ozone formed by UV dissociation of oxygen. In case of ozone, both the heavy isotopes, ^{17}O and ^{18}O, are enriched relative to ^{16}O and the enhancement in ^{17}O / ^{16}O ratio from normal value is almost equal to that for ^{18}O / ^{16}O. It is now known that O + O_2 recombination reaction is an isotopic selective process, where heavy oxygen isotopes get more preference to form stable ozone molecule. However the underlying process for this preference is still not clear. The influence from the symmetry of the molecule is suspected to be the principal cause. To understand this process, a similar type of recombination reaction namely, O + CO yielding CO_2 have been studied. Advantage of studying this reaction is that, CO_2 molecule has a linear form possessing Σ electronic states and O^- atom is present in two equivalent positions. So the wave function possesses a definite symmetry with respect to exchange of the equivalent oxygen nuclei when they are isotopically identical. This makes CO_2 (produced from O + CO reaction) a candidate to show a mass independent oxygen isotopic fractionation similar to that of ozone.

An experiment where ozone was made and subsequently dissociated in visible light to produce ground state oxygen atom, O (^3P), in presence of CO has been designed. O (^3P) undergoes fast isotopic exchange through collision with CO and O_2 (produced from ozone dissociation) and recombines with CO to produce CO_2. The isotopic compositions of O (^3P) and CO are $\delta^{18}O$ = 29.8 ‰, $\delta^{17}O$ = 15.2 ‰ and $\delta^{18}O$ = 28.7 ‰, $\delta^{17}O$ = 14.92 ‰ (relative to VSMOW) respectively. Our results suggest that O + CO $\rightarrow$ CO_2 reaction is not a simple mixing of two different isotopic entities. Instead, the product CO_2 is enriched in heavy isotopes ^{17}O and ^{18}O in a mass independent fashion. The enrichment in CO_2 supports the hypothesis that O + CO $\rightarrow$ CO_2 is a symmetry selective process, with nearly equal preference for the two heavy oxygen isotopes.

(Antra and S.K. Bhattacharya)

Nitrogen Isotope Distribution in Planktons of the Bay of Bengal

First measurement of nitrogen isotopic composition ($\delta^{15}N$) in suspended particulate matter (SPM) of the surface Bay of Bengal (BOB) at 24 different locations during pre- (Apr - May 2003) and post (Sep - Oct 2002) monsoon seasons were made. The $\delta^{15}N$ of particulate organic nitrogen (PON) in surface suspended matter of coastal as well as northern open BOB shows signatures of mixing between continental inputs and marine sources. Average surface PON concentration during post monsoon season (1.4 μM N) is nearly twice that of premonsoon (0.7 μM N). The $\delta^{15}N$ values of surface PON for both pre- and post monsoon season range from 2 to 7.6 ‰ and fall in the general range of known oceanic PON. There is a significant difference of 1.5‰ between average $\delta^{15}N$ of open ocean (4.8 ‰) and coastal (3.3 ‰) stations during post monsoon. Such difference is absent in premonsoon samples. There exists a positive linear correlation between PON and $\delta^{15}N$. During post monsoon the coastal stations show less variability and data points lie in the lower regime i.e., low PON- low $\delta^{15}N$ zone. On the other hand, the open ocean stations show two clusters of data points, one with low PON-low $\delta^{15}N$ and other with high PON-high $\delta^{15}N$. During premonsoon no clear cut distinction exists between $\delta^{15}N$ of PON in coastal and open ocean transects. Dilution by the organic and detrital continental material brought in by rivers leads to consistently lower $\delta^{15}N$ evident from the relationship between surface salinity and $\delta^{15}N$. $\delta^{15}N$ values of surface PON of open ocean locations during both seasons, and also at coastal locations during

premonsoon suggest nitrate from deeper waters to be a predominant source of nutrients for phytoplankton. The depth profiles of $\delta^{15}N$ of PON during the premonsoon season at nine different locations indicate an increase in $\delta^{15}N$ by a maximum of 2.8 ‰ between euphotic depth and 300m, which is lower than that observed in the far eastern Indian Ocean, indicating the role of higher sinking rates of particles ballasted by aggregates of organic and mineral matter in BOB.

(S. Kumar and R. Ramesh)

Trace Element Geochemistry of Amba Dongar Carbonatite Complex

Trace and rare earth element contents of Amba Dongar carbonatites are found to be extremely enriched in Large Ion Lithophile Elements (LILE) compared to those observed in carbonatites elsewhere. The incompatible trace element concentrations show a general increasing trend: alkaline silicate rock < calcite carbonatite < ferrocarbonatite. The contents and ratios of various trace elements clearly show that the calcite carbonatites and ferrocarbonatites of Amba Dongar have fractionally crystallized from a parental carbonate melt. It is also found that the alkaline silicate rocks do not belong to the same crystallization sequence as the carbonatites, instead they represent products of fractional crystallization of a parental silicate melt. Modeling efforts using the concentration data for the rocks of Amba Dongar and experimental partitioning data of nine trace elements for a silicate-carbonate melt system yield results that are consistent with the suggestion that the parental carbonate and silicate melts for the complex have been generated from a mantle derived primary magma as a result of liquid immiscibility.

(Jyotiranjan S. Ray and P.N. Shukla)

Evidence for Large Century Time-scale Changes in Solar Activity in the past 32 Kyr, based on In-situ Cosmogenic ^{14}C in Ice at Summit, Greenland

The fluxes of cosmic rays in Greenland at the Summit (3200 m.a.s.l, 72.6^0 N, 38.5^0 W) were estimated, during the past 32 Kyr. These estimates were derived based on concentrations of in-situ cosmogenic ^{14}C produced in ice crystals. Based on the secular equilibrium concentration of in-situ produced ^{14}C in quartz in terrestrial rocks, it was found that on century time-scales, the cosmic ray production rate of ^{14}C at the Summit was close to its estimated long-term average production rate, except during 3 periods: (i) during 8500-9500y B.P. and 27,000-32,000 y B.P, when the production rate was higher by about a factor of 2, and (ii) during 12,000-16,000y B.P, when the production rate was lower by a factor of ~ 1.5. The observed variation in cosmic ray flux at the polar site is best attributed to changes in solar activity resulting in variable modulation of terrestrial cosmic ray flux. Changes in the geomagnetic field in the past do not affect the cosmic ray flux at polar latitudes. Likewise, climate changes do not affect the in-situ ^{14}C record in ice.

During the first two epochs, the solar activity must have been very low, as during Maunder Minimum, resulting in essentially no modulation of the cosmic ray flux by the solar plasma. During the low cosmic ray flux epoch, 12,000-16,000 y B.P., the observed decrease in cosmic ray flux corresponds to high solar activity as seen in 1958.

The proxy evidence from tree ring and sediment based records of atmospheric $^{14}C/^{12}C$ ratios during the three epochs is discussed. These records have been used as a measure of changes in cosmic ray flux, and solar activity in the past. However, since they are also appreciably affected by climatic changes, a comparison of the two records is potentially valuable for delineating the nature of past changes in solar activity, and large-scale ocean circulation and air-sea exchange.

(**Devendra Lal**, A. J. T. Jull, David Pollard and Loic Vacher)

High Energy X-ray (HEX) Spectrometer for Chandrayaan-1 Mission

The Indian mission to Moon, the Chandrayaan-1, scheduled for launch in late 2007 will include a high energy X-ray spectrometer (HEX) for studying natural emission from the lunar surface resulting from the decay of radionuclides in the U, Th series in the energy interval 20-250 keV. This experiment is designed to investigate the transport of volatiles on the lunar surface through the detection of the 46.5 keV γ ray line from radioactive ^{210}Pb, a decay product of the volatile ^{222}Rn (half-life ~ 4 days), both belonging to the ^{238}U series. This has important bearing on the possible presence of water in the permanently shadowed regions near the lunar poles, suggested on the basis of transport of water molecule (a volatile) from the hot sunlit lunar surface to the cooler polar region. The design and development of the instrument has been initiated in a collaborative manner by PRL and ISAC, Bangalore, and the basic experimental configuration has been finalized. The detector package comprising of pixilated array detector, front-end-electronics (FEE) and HV bias generator is currently being developed at PRL while ISAC will be responsible for the collimator, anti-coincidence system and associated HV and processing electronics. The final integration of the instrument will be done at PRL. The instrument will employ a new generation Cadmium-Zinc-Tellurium (CZT) pixilated array detector with effective area of 100 cm^2 that will detect low energy emissions from the lunar surface with a spatial resolution of 40 km x 40 km.

Response Characteristics of the Pixilated Cadmium Zinc Telluride (CZT) Arrays

CZT arrays manufactured by IMARAD, Israel, and eV Products, USA, are currently considered for the HEX payload. The response characteristics of the IMARAD arrays (**Fig. 8.1a**) having individual pixel of 2.5 mm pitch and array size of 4 x 4 cm (256 pixels) have been determined under different thermal environment over the range of room temperature to - 20 ^{o}C. The response of the detectors shows significant improvement in energy resolution at lower temperature; the energy resolution at 59.5 keV (^{241}Am) line at room temperature is ~12 %

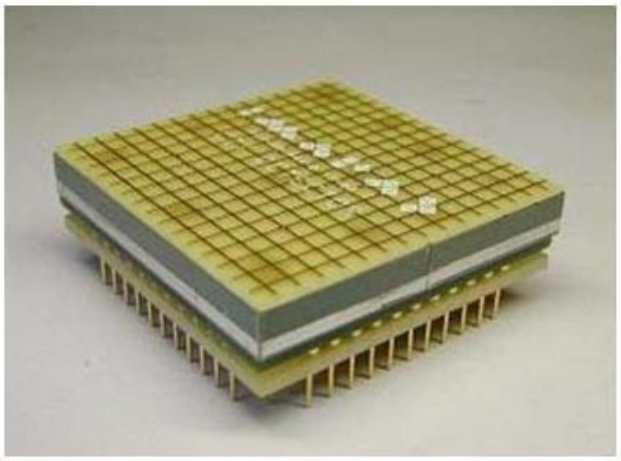


Fig. 8.1a IMARAD CZT coupled to IDEAS ASIC

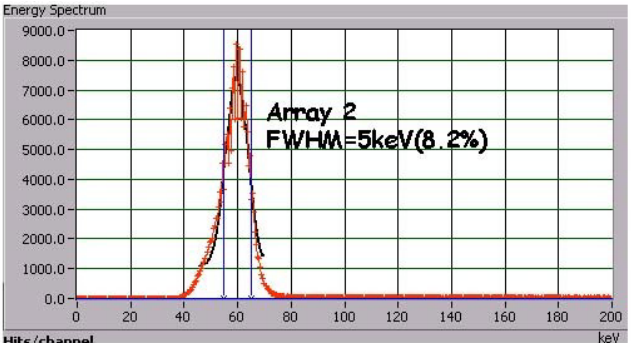


Fig. 8.1b Response of IMARAD CZT to ^{241}Am (59.5 keV) at - 20^{o}C

and decreases to ~ 8 % at - 20^{o}C (**Fig. 8.1b**). These results suggest that use of IMARAD detectors will require effective cooling of the detector module to achieve the desired energy resolution for the HEX spectrometer. Studies of eV product arrays will be initiated soon to finalize the detector for use in this experiment.

Front-end-electronics (FEE) for the HEX Spectrometer

The development of electronics and associated electrical sub-systems for detection of photons in the energy range 20-250 keV using the CZT detector involves several high technology areas that includes ASIC, ASIC control, low noise fast amplifiers and data handling. We plan to use an ASIC developed by IDEAS, Norway. It is a low power, low noise, multichannel inte-

grated circuit that is self-triggered and data driven. Each CZT detector (256 pixels) is supported by two ASICSs, each having 128 charge sensitive amplifiers, shaper and associated controls that provide energy and position (pixel) information for any event (photon) in the form of current. These signals with a typical duration of 1 μs, are processed by front-end-electronics (FEE) comprising of pulse height analyzer (differential current amplifiers, I/V converters, peak detector and ADC), interfacing control and low voltage power systems. Design and testing of FEE to achieve optimum performance of the CZT detector is nearing completion. Various signal simulators and low voltage DC-DC converters have also been developed to test these circuits. A DC-DC converter for generating - 600 V for the bias of the CZT array detectors has also been designed and developed. The design philosophy of the overall system has been reviewed by a task team of the Chandrayaan-1 mission and the suggested modifications are currently being implemented.

Low Energy Gamma Ray Continuum from the Lunar Surface

Remote sensing studies of the composition of planetary surfaces have been traditionally done by studying natural emission of high energy gamma rays (> 300 keV) due to interaction of galactic cosmic rays with planetary surface material. Study of the lower energy emissions, primarily due to decay of radionuclides in the U, Th series, was hampered by the background planetary continuum at these lower energies. The Chandrayaan-1 mission will attempt to measure the natural emission of such low energy gamma rays from the moon for the first time using the HEX spectrometer. The expected low energy lunar continuum background have been studied (**Fig. 8.2**) considering parameters pertinent to the HEX experiment using the CERN software GEANT 4.6.0. Interaction of energetic galactic cosmic ray protons with lunar surface as well as production of secondary neutrons by these interactions that are capable of introducing further reactions resulting in emission of photons from inelastic scattering and from thermal neutron capture reactions have been considered. The gamma rays which escape the lunar surface are monitored along with their kinetic energies to estimate the lunar continuum

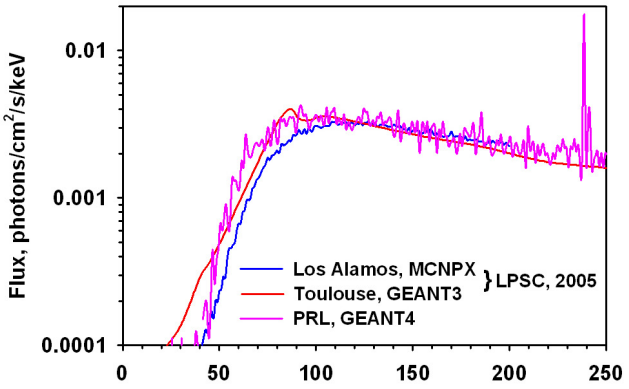


Fig. 8.2 : Low energy gamma continuum fluxes for average lunar composition.. The results obtained by the US (Los Alamos) and French (Toulose) groups were reported at the recent Lunar and Planetary Science Conference.

flux. The lunar continuum fluxes considering various lunar surface compositions have been determined. Results show that below 100 keV, the continuum fluxes are dependent on chemical composition (mean atomic number), whereas above 200 keV, the continuum fluxes are nearly independent of compositions. The lunar continuum signal varies between ~ 0.0001 and 0.003 (cm^{-2} sec^{-1} keV^{-1}) in the energy region 20-250 keV to be studied by the HEX spectrometer. These values are consistent with lunar continuum flux estimates reported recently by two groups from USA and France, using the codes MCNPX and GEANT 3.

Modelling of the Solar X-ray Emission

When solar X-rays interact with atoms in the upper tens of microns of a planetary surface, characteristic X-rays (e.g. K_α line) are produced. The coronal emission spectrum in X-ray region for the period of solar minimum phase conditions between the cycles 23 & 24, appropriate for the proposed Indian lunar mission in 2007 have been calculated. The coronal X-ray emission spectrum is calculated using an analytical model for continuum emission of optically thin plasma whose electrons have a Maxwellian energy distribution for wavelength range 1-1000 angstroms and temperature range 0.01-100 MK. These radiations are produced by free-free, free-bound and two-photon transitions of electrons

for various wavelength and temperature intervals covering the whole range of the spectrum. These X-ray flux estimates will be used to infer the expected lunar X-ray fluorescence emissions.

Reflectance and Imaging Spectroscopy

The reflectance spectra of polished sections of terrestrial and meteoritic samples have been obtained using a spectrometer at SAC over the wavelength region 0.4-2.6 microns. The dependence of reflectance spectra on variations in grain-size as well as mixtures of different minerals in varying proportions have also been studied.

An image processing software (ENVI) is currently used to analyze processed multi-spectral images taken during the Clementine mission over specific areas of the Moon. Mineral maps have been made for these regions for identifying dominant minerals present in these areas and also to generate maps of iron concentration. Studies of areas previously analyzed by several US groups have yielded results consistent with the published data. Studies are currently in progress to analyze raw data from the Clementine mission to generate mineral maps and also to investigate various lunar surface morphology and structures.

Infrared Spectroscopy of Jovian Aurorae

Infrared aurora on Jupiter can be observed from ground based telescopes and may be used to monitor the coupled magnetospheric activity on Jupiter. The wide range of auroral emissions on Jupiter comes from the different species present in the upper atmosphere of Jupiter. H_3^+ molecular ion is one such species which is formed by the interaction of electrons and ions accelerating back into Jupiter's upper atmosphere with atomic

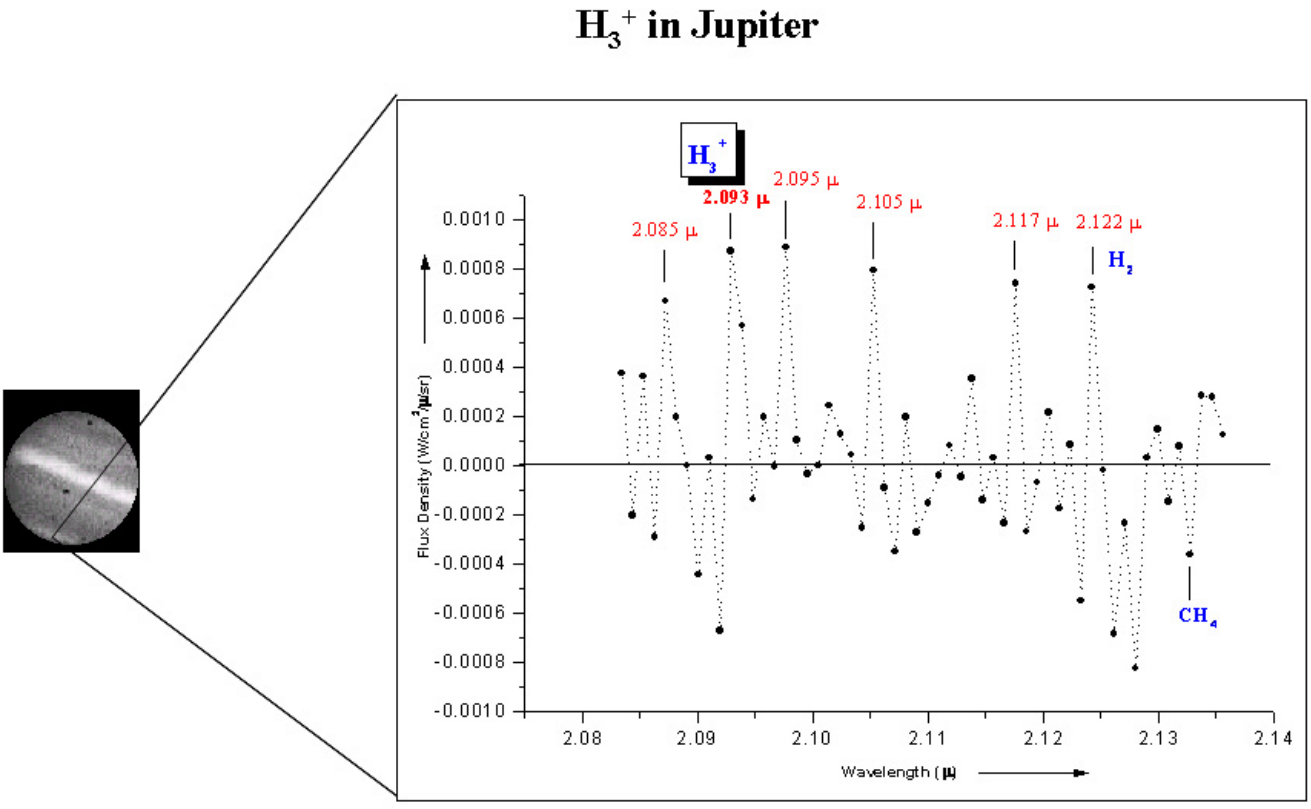


Fig. 8.3 : K' band spectrum of Jupiter taken in the northern auroral zone (System III central meridian longitude of 306 deg) on December 25, 2003 at 23:00 UT. Continuum has been subtracted from the spectra which was then ratioed with a nearby standard star (q Leonis, A2 type) spectrum to remove terrestrial atmospheric absorption.

and molecular hydrogen. Overtone spectra occur when a molecule relaxes back to the ground state after being excited to the second vibrational level. The overtone transition of H_3^+ is at 2.093 microns and can be used to monitor Jovian auroral activity as well as the Jovian plasma characteristics. Using the NICMOS spectrometer and the 1.2 m telescope at Gurushikar at Mt. Abu, the H_3^+ emission at 2.093 microns and the H_2 emission at 2.122 microns has been detected (**Fig. 8.3**). Some additional lines which were detected have been identified using the data reported from observations made from the UK Infrared Telescope and Canadian-French Hawaii Telescope observatories. Further observations are in progress to delineate the spatial and temporal variations of H_3^+ in Jupiter.

Studies of Meteorites Recently Fallen Over Indian

Multiple fall of a stony meteorite occurred near the Dergaon town in the state of Assam, India, on March 2, 2001. Several fragments weighing < 2 kg and a single large fragment weighing ~10 kg were recovered from the strewn field that extended over several tens of square kilometers. Chemical and petrographic studies indicate it to be a H5 chondrite, except for an unusually low K content of ~ 340 ppm. A cosmic ray exposure of 9.7 Ma is inferred from the cosmogenic noble gas records. Low amounts of trapped gases are consistent with the higher petrographic grade of the meteorite. Activities of eleven cosmogenic radionuclides were measured. ^{26}Al and ^{22}Na activities as well as the ^{22}Na/^{26}Al activity ratio are close to the expected values inferred from the data for other recently fallen meteorites and taking into account the solar modulation of galactic cosmic rays. The low ^{60}Co activity (< 1 dpm/kg) is indicative of a small preatmospheric size of the meteorite. Cosmic ray heavy nuclei track densities in olivine grains range from ~10^6 cm^{-2} in samples from the largest fragment to ~ (4 - 9) x 10^5 cm^{-2} in one of the smaller fragments. The combined track, radionuclide and noble gas data suggest a preatmospheric radius of ~ 20 cm for the Dergaon meteorite. This work was carried out in collaboration with groups at the Gauhati University, Assam, and the Open University, UK.

(Y. B. Acharya, D. Banerjee, N. Bhandari, T. Chandrasekhar, D. Dhingra, T. Francis, J. N. Goswami, S.A. Haider V. G. Jardosh, S. Jogani, S. Joshi, A.D. Shukla, P.N. Shukla, G. Koshy, H. D. Mandliya, S.V.S. Murthy, H. L. Patel, M. Shanmugham, K. B. Smart, N. Srivastava, D. V. Subhedar and P. O. Suresh)

Computer Centre

Computer Centre is equipped with IBM RS-6000 SP Computer having 16 processors and 32GB RAM to cater for high computing needs of scientists. Centre also has high-end graphics station, IBM RS-6000 Model 270 with 4 processors to cater to the needs of scientists; POE has also been installed on RS6000/SP and RS6000/270 machines this year. All these machines are connected to our high-speed local area network (LAN) to provide easy, fast and reliable access to more than 300 PC's and few workstations distributed throughout the laboratory. Also, other centres at Udaipur and Mt. Abu are connected to the PRL LAN on 64 Kbps BSNL leased line. Thus full connectivity has been provided to users all the time from anywhere to the Main Campus, Thaltej, USO, and Mt. Abu. The centre provides centralized virus free E-mails by automatically scanning all E-mails. Anti-spam filter has been centrally installed to fight the spam mails. The center also provides web enabled e-mail service. Internet authorizations, monitoring and reporting functions have been added to have optimal usage of internet bandwidth.

Mathematical, numerical and visualization application software like IMSL, IDL, Mathematica, SigmaPlot, Lahey FORTARN 95, Data Explorer etc. have also been installed to cater to the needs of the scientific community. The provision of making colour slides and prints is available. The centre provides consultations and other facilities including archival of file systems, system security, authorization, updating the system softwares, third party softwares and public domain softwares. It also maintains internet connectivity and LAN.

Library

PRL library has been an important part of the laboratory for many years. It is responsible for the collection development and processing of library materials for the libraries in all the four campuses of PRL – PRL Main Campus, Thaltej, Mt. Abu and Udaipur Solar Observatory. It has a rich collection of over 55,000 documents which includes 19,000 books, 31,000 bound volumes of journals, 600 audio visual (A-V) documents, 700 reports and 3500 reprints of PRL authors. It subscribes to 137 international and national journals which includes seven new titles. One hundred and ten journals can be accessed online. Also it is subscribing to few e-books from Springer. It is probably the only library in India to initiate automation in the early sixties with the development of the Mechanized Indexing using the first IBM-1620 computer. Since then the library systems and services have grown tremendously. With the acquiring of the LIBSYS software, the circulation desk and all its functions have been automated. The current awareness service now includes intimation of new arrivals of books through e-mail. The library also provides the web OPAC (Online Public Access Catalog).

The library has added 172 books in English and 116 books in Hindi to its collection. It has fulfilled 315 ILL requests from other libraries and received 140 documents on ILL from other libraries. The library procured 6 articles from STN, which is a paid Document Delivery Service. About 1 lac of photocopies were taken out from the in-house photocopying machine in this period.

PRL library is in the process of establishing a digital library which will include the PRL archive and its repository. The PRL publications and PRL doctoral theses from 1995 onwards are being digitised. Almost 1000 papers and 25 theses have been made available over the LAN.

A consortium has been formed consisting of FORSA (Forum for Resource Sharing in Astronomy and Astrophysics) members to access the journals in electronic format. A consortium basically gives much broader access base than is possible by any individual library i.e. individual institute libraries continue subscribing to the required journals in print and all the members can access all the journals subscribed by the whole group. Nature online and Springer journals (online) have been subscribed by the FORSA group.

The library staff also imparts training to the library trainees in the all the aspects of the library functioning. Four trainees received training this year.

Workshop

PRL workshop is a general-purpose workshop that provides extensive support to scientists and engineers.

Tripod assembly and universal joint for Hexapod fabricated in the Workshop

The workshop is having wide range of machines such as metal cutting machines, welding machines and CNC Lathe machine in machine shop. The workshop plays an important role in designing, developing and manufacturing the precise mechanical components and helps the scientists to establish various systems for different experimental groups.

The workshop also carries out sheet and structural metal fabrication jobs. The high vacuum welding joints is also carried out by using TIG welding machine. The workshop is equipped with one CNC Lathe Machine to carry out precise turning jobs.

Some of the major work carried out during the year is listed below:

A Reaction Vessel for Lithium Carbide Preparation

A reaction vessel was designed and fabricated using SS-304 grade quality material. The vessel size was 200 mm diameter and 340 mm length. This was machined from a solid round bar having radius turning, taper turning and inside / outside turning with close tolerances.The vessel is made from single piece to avoid welding joints and gas trapping. The vessel is finished to a high surface finish grade to avoid any kind of carbon trapping and sample contamination during carbide preparation.

Speleothem Sample Cutting

Speleothems are carbonate deposits that occurs in lime stone caves. The very hard sample rocks were cut to different sections using Vertical band Saw machine. An utmost care was taken to cut the different thin sections as required by scientists.

Vacuum Crusher

A high vacuum stainless steel crusher was designed and fabricated. This is used to crush sample from which the trapped gases are collected and supplied to mass spectrometer for scientific analysis. This job involves high precision machining and surface finish of cylinder, housing, piston and coupler.

Hexapod / Tripod

The precise mechanical components for proto type Tripod assembly were fabricated which includes precision S.S. flanges, couplings, other parts and a universal joint. All the components were made with high accuracy and surface finish. The picture of Tripod assembly and universal joint is shown above.

Engineering Services

The engineering services section renders all the technical services pertaining to the civil, electrical and air-conditioning works. This section also looks after the upkeep and the efficient functioning of the internal telephone system, elevators, and maintenance of all the official buildings, offices, and residential buildings in the various campuses. These jobs include architectural planning, designing, estimating and execution of the various civil works landscaping, horticultural development, interiors & furnishings of the buildings & structures of all the six campuses situated at Ahmedabad, Mt. Abu & Udaipur.

During the year following work were completed :

i. Renovation of PDF quarter block – A.

ii. Construction of New Gate Complex, PRL Main Campus.

iii. Construction of Patrol road along boundary wall in PRL staff quarter colony, Vikramnagar.

iv. Replacement of windows for PRL main building

v. Renovation of toilets, thaltej campus.

Following works are in progress:

i. Renovation of front building, PRL main campus.

ii. Renovation of DIAL lab.

iii. Renovation of double storied quarters in PRL colony, Navrangpura.

iv. Construction of staff colony, USO, Udaipur.

Honorary Fellows

Honorary Fellows

Professor J.E. Blamont

Acad. V.L. Ginzburg

Professor A.M.J. Tom Gehrels

Professor D. Lal

Professor M.G.K. Menon

Professor U. R. Rao

Prof. P. Crutzen

Prof. K. Kasturirangan

Prof. A. Hewish

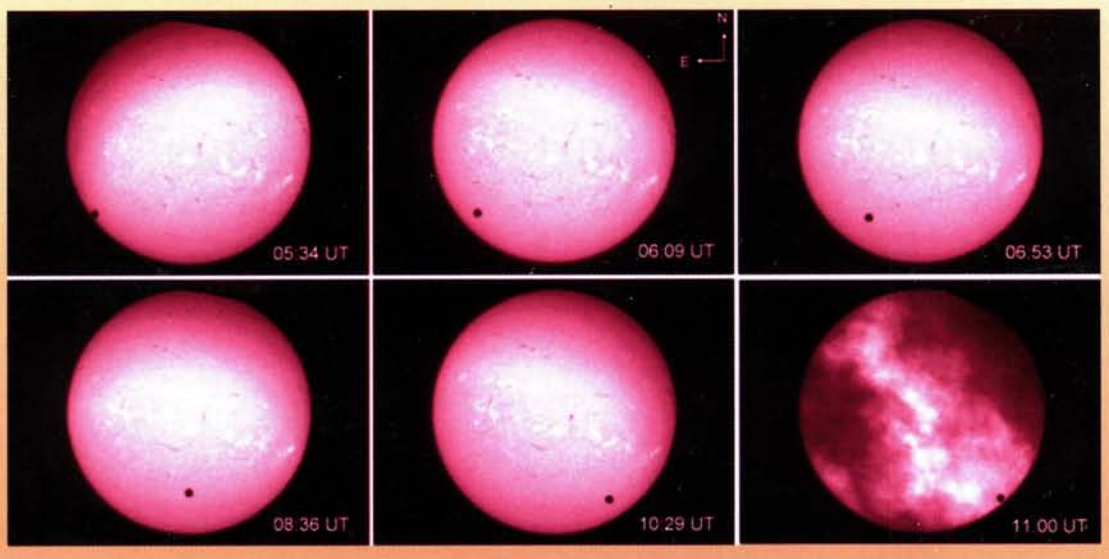
Academic Faculty

Academic Faculty

Name	Specialisation	Academic Qualification
Prof. G. S. Agarwal FNA, FASc, FNASc,FTWAS	Quantum Optics, Nonlinear Optics and Laser	Ph D Rochester Univ. (1969)
Prof. N. Bhandari FNA, FASc, FNASc	Planetary Physics	Ph D TIFR Bombay Univ (1967)
Prof. S. Krishnaswami FNA, FASc, FNASc, FTWAS	Aqueous Geochemistry and Nuclear Oceanography	Ph D TIFR, Bombay Univ. (1974)
Prof. D. P. Dewangan	Atomic and Molecular Physics	Ph D Calcutta Univ. (1973)
Prof. J. N. Goswami FNA, FASc, FNASc, FTWAS	Solar System Studies (Pre - Solar Processes)	Ph D PRL, Gujarat Univ. (1978)
Prof. V. K. B. Kota	Nuclear Physics	Ph D Andhra Univ.(1977)
Prof. A. S. Joshipura FASc, FNASc	Particle Physics	Ph D Bombay Univ. (1979)
Prof. A. K. Singhvi FNA, FASc, FNASc, FTWAS	Palaeoclimatology and Geochronology	Ph D IIT, Kanpur (1975)
Prof. S. K. Bhattacharya FASc	Isotope Geochemistry	Ph D PRL, Gujarat Univ. (1980)
Prof. V.B Sheorey	Theoretical Atomic Physics & Nonlinear Dynamics	Ph D Univ. College, London Univ (1968)
Prof. P. Venkatakrishnan	Solar Physics	Ph D, Bangalore Univ. (1984)
Prof. S. D. Rindani	Particle Physics	Ph D IIT, Bombay (1976)
Prof. Harish Chandra	Ionospheric Studies	Ph D PRL, Gujarat Univ. (1970)
Prof. B. G. A. Rao	Star formation, Planetary Nebulae, AGB Stars and Imaging Fabry Perot Spectroscopy	Ph D PRL, Gujarat Univ. (1978)
Prof. Shyam Lal FNA, FASc	Atmospheric Chemistry of Trace Gases	Ph D PRL, Gujarat Univ. (1982)
Prof. R. Ramesh FNA, FASc, FNASc	Isotope Geochemistry	Ph D PRL, Gujarat Univ. (1984)
Prof. M. M. Sarin FASc	Geochemistry and Oceanography	Ph D PRL, Gujarat Univ. (1985)
Prof. U. C. Joshi	AGNs, Milky way, Star Formation and Comets	Ph D Kumaun Univ. (1981)

Name	Specialisation	Academic Qualification
Prof. R. E. Amritkar FASc	Nonlinear Dynamics & Chaos	Ph D IISc, Bangalore (1978)
Prof. Utpal G. Sarkar	Particle Physics	Ph.D Calcutta Univ. (1984)
Prof. H. S. S. Sinha	Upper Atmospheric and Ionospheric Studies	Ph D PRL, Gujarat Univ. (1977)
Prof. N. M. Ashok	Close Binary Stars, Novae, IR studies	Ph D PRL, Gujarat Univ. (1983)
Prof. A. Jayaraman	Atmospheric Aerosols and Radiative Studies	Ph D PRL, Gujarat Univ. (1985)
Prof. S. V. S. Murty FASc	Isotope Cosmochemistry	Ph D IIT, Kanpur (1981)
Dr. Hemant H. Dave	Laser Spectroscopy and Space Instrumentation	Ph D, Univ. of Lowell, Mass., USA (1980)
Dr. S. K. Gupta FNASc	Geophysics, Hydrology	Ph D IIT, Bombay (1974)
Dr. T. Chandrasekhar	High Angular Resolution Studies, Late type stars, Solar Coronal Studies, Comets	Ph D PRL, Gujarat Univ. (1982)
Dr. Hari Om Vats	Space Weather & Radio Astronomy	Ph D PRL, Gujarat Univ. (1979)
Dr. A. K. Ambastha	Solar Plasma Physics	Ph D PRL, Gujarat Univ. (1981)
Dr. K. S. Baliyan	AGNs, Comets, Atomic Physics	Ph D Roorkee Univ.(1986)
Dr. Kanchan Pande	Geology, Geochronology	Ph D PRL, Gujarat Univ. (1990)
Dr. J. Banerji	Laser Physics	Ph D City Univ.(New York)(1982)
Dr. D. P. K. Banerjee	Novae, Be Stars, Planetary Nebulae, IR and Optical Studies	Ph D PRL, Gujarat Univ. (1991)
Dr. Syed Aftab Haider	Planetary and Cometary Atmospheres	Ph D Banaras Univ. (1984)
Dr. P. Janardhan	Solar Radio Astronomy & Space Weather	Ph D PRL, Gujarat Univ. (1992)
Dr. R. Sekar	Upper Atmospheric and Ionospheric Physics	Ph D PRL, Gujarat Univ. (1991)
Dr. Subhendra Mohanty	Astroparticle Physics	Ph D Wisconsin Univ. (1989)
Dr. Rajmal Jain	Solar Physics	Ph D PRL, Gujarat Univ. (1983)

Name	Specialisation	Academic Qualification
Dr. J. R. Bhatt	Astrophysics	Ph D PRL Gujarat Univ. (1992)
Dr. A. Lakshminarayan	Nonlinear Dynamics & Quantum Chaos	Ph D State Univ.,New York (1993)
Dr. H. Mishra	Strong Interaction Physics & Nuclear Astrophysics	Ph D, Utkal Univ. (1994)
Dr. R. Rangarajan	Particle Physics & Cosmology	Ph D, Univ. of California, Santa Barbara (1994)
Dr.P.K. Panigrahi	Field Theory	Ph D, Rochester Univ. (1988)
Dr. P. N. Shukla	Geochemistry	Ph D IIT, Kanpur (1977)
Dr. P. Sharma	Geophysics and Hydrology	Ph D PRL, Gujarat Univ. (1977)
Dr. J. R. Trivedi	Geochronology	Ph D PRL, Gujarat Univ. (1991)
Dr. Ashok K Singal	Radio Astronomy & Astrophysics	Ph D TIFR, Bombay Univ.(1986)
Dr. K. P. Subramanian	Experimental Atomic and Molecular Physics	Ph D PRL, Gujarat Univ. (1987DDr.
Dr. S. Ramachandran	Atmospheric Physics	Ph D, PRL, MS Univ. (1996)
Dr. R. P. Singh	Laser Physics	Ph D, JNU, N. Delhi (1994)
Dr. Varun Sheel	Modelling of Lower Atmosphere	Ph D, PRL, Guj. Univ. (1996)
Dr.(Ms.) N. Srivastava	Solar Physics	Ph D, PRL, Ravi Shankar Shukla Univ. (1994)
Dr. Bhas Bapat	Atomic Collisions	Ph D, TIFR, Mumbai Univ. (1997)
Dr. Bimalendu Deb	Quantum Optics	Ph D, Jadavpur Univ. (1997)
Dr. Angom D. Singh	Atomic Physics	Ph D, IIA, Bangalore Univ. (1998)
Dr. D. Banerjee	Thermoluminscence	Ph D, PRL Gujarat Univ. (1996)
Dr. J. S. Ray	Isotope Geochemistry	Ph D, PRL, MS Univ. (1997)
Dr. S. K. Singh	Isotope Geochemistry	Ph D, PRL, MS Univ. (1999)
Dr. Shibu K. Mathew	Solar Magnetic & Velocity Fields	Ph D, PRL, Gujarat Univ. (1999)
Dr.. M. S. Santhanam	Non-linear Dynamics & Time Series Analysis	Ph D, PRL, Gujarat Univ. (1999)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