वार्षिक रिपोर्ट
Annual Report
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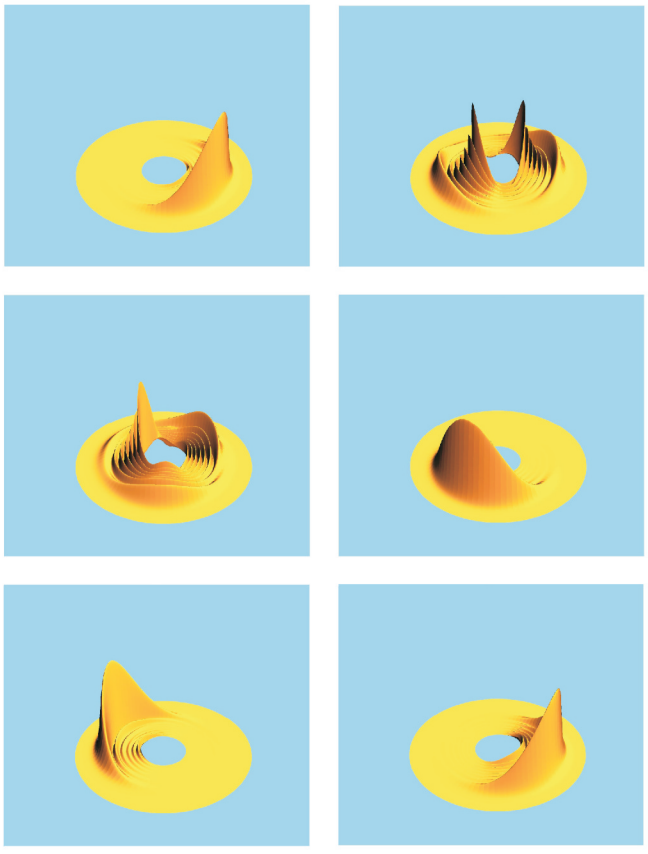

भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद
Physical Research Laboratory, Ahmedabad

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Introduction

Physical Research Laboratory is a premier institute engaged in basic research in the areas of Astronomy & Astrophysics, Solar Physics, Space & Atmospheric Sciences, Planetary & Geosciences and Theoretical Physics. The research activities cover a wide spectrum of topics in the above areas using state-of-the-art approaches and have been well recognized by peers at both national and international level. The Laboratory is also involved in human resource development and conducts extensive academic programmes for doctoral and post-doctoral research, has an Associateship programme for university teachers and conducts summer programmes for M.Sc. students.

A major academic event during the year was the second decadal review of scientific works carried out by the four major research Divisions of the Laboratory by four Review Panels consisting of both Indian and foreign experts. The inputs received from the panels were considered in formulating the Eleventh Five-Year Plan proposal of the Laboratory.

Another upcoming significant milestone for the Laboratory will be on November 11, 2006 when it will enter its sixtieth year. An extensive year-long programme has been chalked out to celebrate the Diamond Jubilee year of the Laboratory during 2006-2007.

Significant achievements in various fields of research have been made by PRL during the last year. These are described in detail in this report. A glimpse of some of these is briefly outlined here.

The Astronomy & Astrophysics Division continued its study of nova-like outburst of V838 Monocerotis, for which a light echo was detected in visible and near infra-red region from Mt.Abu telescope. The group obtained time on Spitzer Space Telescope to observe this object in far-infrared and detected a rare infra-red echo representing an extended nebulosity that also has striking similarity with the optical image obtained by Hubble Space Telescope. The estimated mass of the material responsible for the light echo suggests an interstellar rather than circumstellar origin for the same. The group has also detected a near infra-red flash from the afterglow of GRB050319 that faded in about ten minutes, an observation that was unexpected and suggestive of new aspects of GRB afterglows.

The Solar X-ray Spectrometer (SOXS) on board GSAT-2 continues to provide new data on solar flare and several additional flares where brightening took place significantly away from the primary site. Interaction of small loops of emerging flux lines with pre-existing large loops of main active regions appears to be the cause of triggering such flares characterized by remote brightening.

A team from the Udaipur Solar Observatory (USO) observed the total solar eclipse on March 29, 2006 from Manavgat-Antalya in Southern Turkey. The observed duration of totality was 3 min 44 sec. Digital images of the corona using filters centered around green-line 5303 Å (FWHM 1.6 Å), 5303 Å (FWHM 12 Å), H-alpha 6563 Å (FWHM 12 Å) and a neutral density filter yielded important data on coronal emission line polarization.

The first results from the newly developed solar vector magnetograph attracted international attention and led to the formulation of a multi-institutional proposal under the Indo-French programme of the DST. USO also participated in a campaign under the CAWSES India programme aimed at understanding space-weather phenomena driven by solar events.

Lidar observations made by the Space & Atmospheric Sciences Division during the second ISRO GBP land campaign in December 2004 at Delhi showed that during foggy condition there was a collapse in the vertical distribution of aerosols to a shallow height of about 200 m, which led to an increase in the surface values of aerosol concentration by a factor of two to five. Intrusion of stratospheric ozone has also been observed in the upper troposphere over Kanpur on a strong foggy day.

Laboratory simulation study carried out by this Division showed that velocity profiles of laser- produced plasmas depend not only on the atomic mass of the target, but also on the ambient pressure. At low ambient pressures, the expansion velocity decreases with increasing mass. At higher pressures, reverse trend was observed. Contrary to the expectation, the ejected material did not homogenize at high ambient pressures.

Li-Be isotope studies of early solar system solids carried out by the Planetary and Geosciences Division did not confirm the presence of the extremely short-lived nuclide ^{7}Be (half-life ~ 56 days) in early solar system, claimed by a French-US group recently. The presence of this nuclide would have suggested interaction of energetic solar particles as a major source of some of the short-lived nuclides present in the early solar system. Our results rule out this possibility and indicate that a stellar origin remains the most probable source of the now-extinct short-lived nuclides present in the early solar system.

Studies of Sr and Nd isotope composition of sediments of the Ganga and the Brahmaputra rivers carried out by the Division show that the Higher Himalaya is the primary source for these sediments and that the Himalaya is undergoing differential erosion. It is seen that basins with high relief, such as the Gandak in the Ganga Basin and the Eastern Syntaxis of the Brahmaputra, are eroding very rapidly at rates of ~ 6 and 14 mm/y respectively compared to other regions of these basins which have erosion rates of ~ 2 mm/y.

Scientists from the Division have also participated in the second expedition to the Southern Ocean and Antarctica organized by NCAOR, Goa. The southern Ocean is rich in nutrients such as nitrate and poor in Chlorophyll, and is termed as HNLC (High Nutrient Low Chlorophyll) region. Experiments using ^{15}N tracer to measure the new and total production in the Southern Ocean and also in the coastal waters off the Antarctic continent were conducted. The data obtained should lead to a better understanding of the Southern Ocean biogeochemistry.

By analyzing oxygen isotopic records in three different species of foramenifera in a radio carbon dated sediment core from the south-eastern Arabian Sea, scientists from the Division have documented clear evidence of the role of solar forcing on the Indian South West Monsoon strength during the last 10,000 years.

The Theoretical Physics Division with broad areas of interests in High Energy Physics, Astroparticle Physics & Cosmology, Non-linear Dynamics & Complex Systems and Quantum Optics & Quantum Information have made significant contributions in all the areas. The high-energy physics group proposed a split-supersymmetric model in the context of a universe with extra spatial dimensions and also a SO(10) GUT model that is consistent with experiments. The Astroparticle Physics group considered the observed spatial anisotropy in the cosmic microwave background assuming certain initial state of the inflation to set some limit on the temperature of the inflation. Several interesting properties of self-synchronization in complex systems have been obtained. Studies on entanglement in a special family of non-classical states, the pair-coherent states have been carried out. A scheme to entangle two mesoscopic system of the same type through a third mesoscopic system and plausible teleportation experiment in such systems has been proposed. Interesting results have also been obtained in the area of fractional revival of quantum wave packets.

The design of the High Energy X-ray (HEX) Spectrometer to be flown on Chandrayaan-1 mission is being carried out by the Planetary Sciences and Exploration (PLANEX) group at PRL and ISRO Satellite Centre (ISAC), Bangalore. PRL is responsible for developing the detector module, front-end electronics and integration and check-out of the final payload in collaboration with Space Applications Centre (SAC), Ahmedabad. Breadboard models for front-end electronics have been designed and successfully interfaced with the detector module. The engineering model should be ready by the end of 2006 with delivery of the flight model scheduled for middle of 2007.

PRL scientists have made significant contributions at the national and international scene with a large number of publications in high impact journals. Several of our scientists are on the Editorial boards of reputed national and international journals. A total of *one hundred and thirteen papers* have been published in high impact journals, of which *ninety one* were in international journals. PRL scientists participated actively in national and international conferences with large number of significant presentations, out of which *eighty seven*, were invited talks. At present, PRL has *fifty nine* research scholars and *eleven* post-doctoral fellows besides other visitors

working in various disciplines. Four Ph.D. and one M.Tech theses were submitted during the year.

Several of our scientists have been honoured with national and international awards. These include *Fellowships of the Science Academies of India, Astronautical Society of India Award, Eminent Mass Spectrometrist Award and BOYSCAST Fellowship of DST*.

Prof. Satish R. Shetye, Director, National Institute of Oceanography, Goa visited PRL and delivered the twenty first Prof. K. R. Ramanathan Memorial Lecture on *The Indian Summer Monsoon & the North Indian Ocean.*

Shri G. Madhavan Nair, Secretary, DOS/ Chairman, ISRO, Govt. of India, visited PRL on November 24, 2005 and delivered an address on *Department of Space: Future Direction.*

On the occasion of the Foundation Day of PRL, **Prof. S. P. Pandya**, former Director, PRL delivered a popular lecture on *Dr. Vikram A. Sarabhai.* In addition, lectures highlighting the *Nobel Prize in Physics for the year 2005* were delivered by **Dr. P. K. Panigrahi** and **Dr. Dilipkumar Angom**, both from PRL.

The **Year of Physics-2005**, marking the hundredth year of publication of Einstein's three seminal papers on Photoelectric Effect, Brownian Motion and Special Relativity that changed the course of physics in the twentieth century, was celebrated world over by holding conferences, seminars, lectures and exhibitions on the life and work of Albert Einstein. The Laboratory also organized a series of sixteen popular lectures and technical seminars by its scientists as well as eminent scientists from other institutions during August-December 2005. The speakers for public lectures included **Prof. P. C. Vaidya** *on Einstein's Universe* and **Prof. J. V. Narlikar** *on Cosmology in the Post-Einstein Era.*

The 6th PLANEX Workshop on **Remote Sensing and Chandrayaan-1 Mission** was held at NRSA, Hyderabad, during October 23 - 28, 2005. Thirty applicants, mostly M.Sc. students and research scholars and a few young faculty from different parts of the country attended the Workshop. Based on their performance during the Workshop, four participants were short-listed for possible future training opportunities in the PLANEX program at PRL.

On the occasion of the **30th Anniversary of the Fall of Dhajala Meteorite** in Gujarat, wherein PRL scientists were involved in the collection, documentation and scientific investigations, a one- day workshop was organised at PRL on January 29, 2006. The primary aim was to apprise the college and university teachers and students of the advancement in planetary sciences in the last thirty years, and the importance of meteorites in this regard. The workshop was enthusiastically attended by over two hundred students and teachers, including a special contingent of twenty people from Dhajala village, who were involved in the collection of Dhajala meteorite at the time of its fall.

During February 27-March 2, PRL convened the **Meeting of the Executive Committee of the International Quaternary Union and a One-day Symposium on Quaternary Studies** with emphasis on India. Over fifty scientists from seven countries and twenty institutions participated in the Symposium. The range of topics covered included paleohydrology, paleoseismology, paleoclimatology and mapping related to Quaternary studies. Linked to these events PRL also organized a DST-sponsored **Brain-storming Session on Paleoclimate Research in India** that was attended by invited experts. A baseline paper outlining future directions of paleoclimate research with a decadal perspective was prepared.

A Workshop on **Remote Sensing and Chandrayaan-1 Data Analysis** was organized during March 6-7, 2006 at Physical Research Laboratory to bring together scientists from various universities and organizations having exposure to remote sensing data analysis and interested in participating in Chandrayaan-1 data analysis program. The workshop was attended by twenty nine external participants and sixteen participants from PRL. Lectures were given by various experts from PRL, SAC, ISAC, NRSA and ADRIN on concepts and applications of satellite remote sensing, remote sensing payloads on Chandrayaan-1 and remote sensing data analysis. The participants were mostly from universities, IITs and other national research institutions.

PRL hosted the **XXI SERC Main School in Theoretical High Energy Physics** from February 11 - March 3, 2006, in which 34 students and 8 faculty members from all over the country participated. The aim of the SERC School was to give Ph.D. students a pedagogical introduction to current areas of research. The topics covered in this school were particle physics phenomenology, strong interactions, black hole physics and cosmology.

The annual **RESPOND Review Meeting** was held in PRL during March 24-25, 2006. The meeting reviewed about twenty three projects in various areas of space sciences. The RESPOND Programme on space sciences sponsored by ISRO and administered by PRL provides unique opportunity to scientists in universities and institutions to carry out research projects in different areas related to space sciences.

The PLANEX Group organized a meeting on March 5, 2006 at PRL to **review the status and progress of various PLANEX supported projects.** Presentations were made by the Principal Investigators of PLANEX supported projects. The meeting concluded with a general discussion on the future direction of PLANEX programmes amongst the participants and the reviewers.

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, 2005. The training programme aims to acquaint and expose the students and teachers with research activities of PRL. Nineteen undergraduate and post- graduate students and two college teachers participated in the programme.

As a part of implementation and progressive use of Hindi in PRL, the **Hindi Pakhwada** was celebrated at PRL from September 14 - 28, 2005. The highlights of the celebrations included word quiz, essay writing, elocution contest, Hamara Karya, self-written poetry competition. The celebration was inaugurated by Prof. Raghuveer Chaudhury, former Head, Hindi Department, Gujarat University and an eminent writer in Hindi and Gujarati.

PRL conducted a **One-day Seminar in Hindi on Contributions of PRL in the Field of Science & Technology** on March 24, 2006, in which eleven talks were presented by PRL members. The key note address was delivered by Prof. J.N. Goswami, Director, PRL. Shri B.S. Bhatia, Director, DECU, SAC, Ahmedabad delivered the inaugural address on *Hamari Vaigyanik Virasat Aur Naya Sandarbh*. PRL personnel also participated in **DOS Inter-Centre Technical Seminar** in Hindi held at ISAC, Bangalore during November 25-26, 2005 in which four papers on various topics were presented.

PRL celebrated the **National Science Day,** in association with the Indian Physics Association (IPA), Ahmedabad Chapter on February 25, 2006. Teachers and students from more than two hundred and ninety schools from all over Gujarat participated in this event that comprised of science quiz, both written and oral, for students of Stds. IX and X, popular lectures, exhibition and interactive quiz for the teachers. The interactive open quiz was on Nurture Nature for the Future. Highlights of the celebration included talks on Water Management and movies on Nanotechnology and Water and Environment related topics. In addition, the Centre for Environmental Education organized an exhibition and puppet show on Prakriti.

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.

Overall, we had a productive and scientifically rewarding year and I look forward to have an even more fruitful Diamond Jubilee Year 2006-2007.

I take this opportunity to thank all my academic colleagues and also the administrative, technical and supporting staff for their co-operation. I am grateful to the PRL Council of Management for guidance and advice.

(Director)

PRL in a Nutshell

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

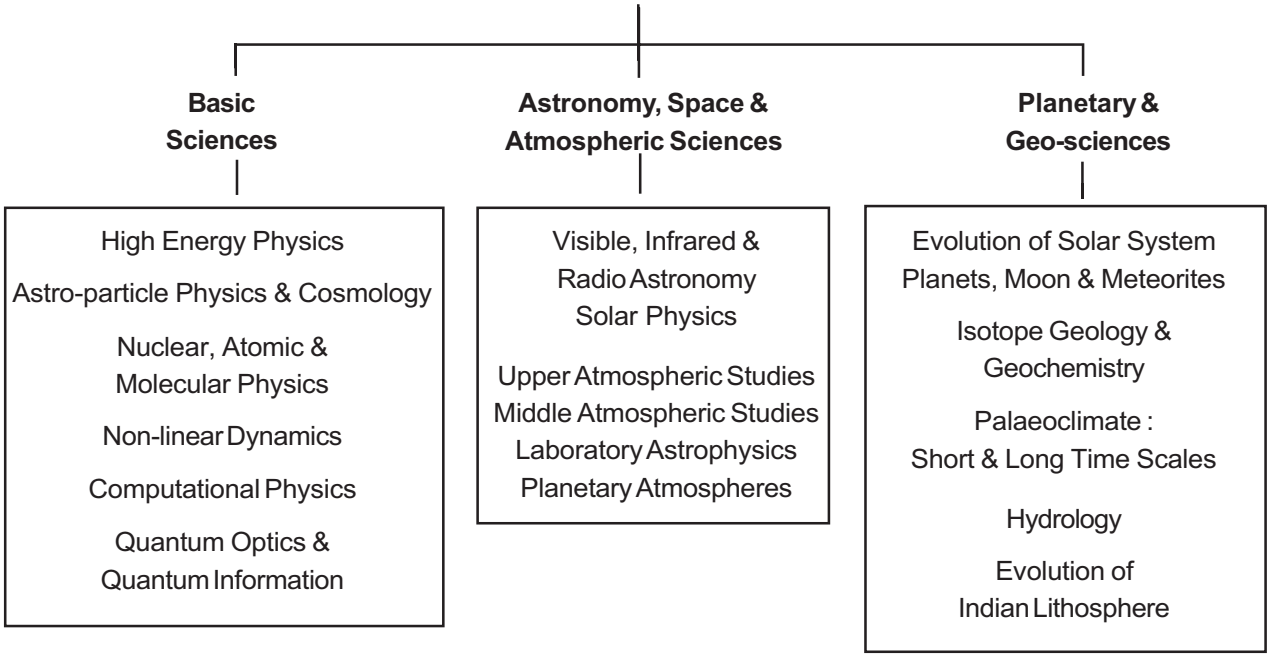
Astronomy and Astrophysics

The main activities of the division concern investigations related to star formation, stellar evolution, eruptive variables, inner parts of the milky way galaxy and active galactic nuclei and blazars. The 2002 outburst of V838 Monocerotis has turned out to be one of the most interesting events in the field of eruptive variables in recent years. This star has expanded to unusually huge - referred to as hypergiant - dimension and cooled down to very low temperature regime of brown dwarfs. In addition, the spectacular light echo resulting from scattering due to dust particles continues to expand and displays lot of structures. New insights were obtained using the Spitzer Space Telescope to image the light echo at far-infrared wavelengths where the extremely cool dust particles radiate very effectively. An extended nebulosity - a rare infrared echo - is clearly detected and it has striking similarities with the optical images obtained by the Hubble Space Telescope. The mass of the IR light echo material is inferred to be several tens of solar mass and suggests an interstellar origin for the light echo rather than circumstellar remnant due to mass loss episodes from previous outbursts.

A bright near-infrared flash from the afterglow of gamma-ray burst GRB 050319 was detected 6.15 hours after the burst. The IR flash rapidly faded by a factor of ten in about 10 minutes. Such a late IR flash in GRBs is unexpected and suggests a new aspect about GRB afterglows that needs to be explained.

The high angular resolution study of carbon stars by lunar occultation technique has provided constraints on the amount of circumstellar matter around SS Vir. The direct measurements of chord lengths along the occultation path have been obtained for two asteroids 7 Iris and 11 Parthenope, the values being 193 and 139 km.

Profile of Scientific Activities



The post-outburst observations of young eruptive stellar variable V1647 Orionis have shown that the object has faded to its pre-outburst brightness in about 2 years indicating that the outburst was of EXor type.

The division members also participated in a national multi-wavelength campaign on the micro-quasar SS 433 by contributing near-infrared photometric measurements. These observations revealed sharp variations in intensity on time scales of a few minutes and this is attributed to shock oscillations in the jets of SS 433.

The intra-day polarization changes have been detected in the BL Lac object Mrk 501 and this indicates a gradual increase in the degree of polarization due to alignments of the magnetic field in the blobs inside the relativistic jet.

The study of radio emission from solar flares was done at decimeter wavelengths that comes from energetic electrons and can be used as diagnostic probe to map the magnetic field lines in solar flares. The images obtained with GMRT were compared with microwave images from Nobeyama Radio Heliograph. This study has suggested that the radiating electrons are trapped near the tops of the magnetic loops and consequently have pitch angles close to 90 degrees.

Solar Physics

Research activity at USO is centred around various aspects of solar activity and the processes influencing space weather. The super-active regions observed in October-November 2003 continue to provide vital clues on such processes. A study of the interplanetary properties of the CME shows that the magnitude of a geomagnetic storm is strongly influenced by (a) the time for which the interplanetary-magnetopsheric coupling parameter was active and (b) the orientation of the magnetic cloud axis. Along with active regions, quiescent prominences were also examined for CME precursors. It was found that the characteristic slow rise of eruptive prominences might be considered as the most reliable of all CME precursors. A study of sunspot brightness at different phases of the solar cycle did not confirm the variation reported by earlier investigations.

The first vector magnetograms measured with the prototype instrument were used to find sensitivity of acoustic power to the inclination of the magnetic vector to the line of sight. The development of the adaptive optics system is in progress, while the procurement of a new large Multi - application Solar Telescope (MAST) is in an advanced stage.

Solar X-ray Astronomy and Submillimetre Science

Solar X-ray Spectrometer (SOXS) on-board GSAT-2 has observed unique set of flares chatacterised by brightening significantly away from the primary site of the flare, called remote brightening, seen in other wavelengths. SOXS observations when combined with optical and radio waveband observations revealed that interaction of newly growing small loops of emerging flux region (EFR) with pre-existing large loops of main active region is a suitable mechanism for triggering the flare in general, and remote brightening in particular. Study of large number of X-ray spectra of micro-flares observed by SOXS mission revealed that the physical process triggering them appears to be thermal plus non-thermal hybrid mechanism.

Sub-millimeter spectroscopic survey of a few coolants were carried out in dark cloud L134N and physical parameters were deduced with the aid of Radiative transfer codes. Laboratory Local Oscillator (LO) is calibrated and characterized for CH_3OH and HCOOH gases. Routine operation of LO is established at 70.6, 86.2, 96.5, 118.8, 163, 393.6, 418.6, 432.6, 495, and 513 μm lines. Long and short term stability of the system is studied. Beam profile analysis of all observed lines has been completed. A versatile gas cell is designed and fabricated to carry out systematic study of molecular transition characteristics of linear, asymmetric, and deuterated molecular systems. A high resolution state-of-the-art Chirp Transform Spectrometer (CTS) has been designed with ability to process 200 MHz IF bandwidth with centre frequency 600 MHz and frequency resolution 40 kHz. Performance of Chirp processor has been verified by simulations.

Theoretical Physics and Complex Systems

The main activities of the theoretical physics and complex systems division are concentrated in the areas related to (i) High Energy and Astroparticle Physics (ii) Nonlinear Dynamics and Complex Systems and (iii) Atomic and Molecular Physics.

In the area of high energy physics the emphasis has been on collider physics, extension of the Standard Model of particle physics, strong interaction physics and in the application of particle physics in cosmology. In the next decade or so, new experimental results are expected from the Large Hadron Collider (LHC) and the proposed International Linear Collider (ILC). The group has been active in identifying and providing theoretical expressions for variables associated with the scattering and decay of particles in collider experiments that can be used to distinguish between different extensions of the Standard Model. In particular, the emphasis has been on the role polarized beams can play in improving the sensitivity of experiments to new physics.

One of the extensions of the Standard Model involves a symmetry between bosons and fermions known as supersymmetry. In supersymmetric theories, for every fermion (boson) in the theory there is a supersymmetric partner which is a boson (fermion) with the same gauge charges. Since no supersymmetric partners of Standard Model particles have so far been detected in any experiment it is believed that these supersymmetric particles must be too heavy to have been produced in colliders. Split supersymmetric models have been proposed in which the supersymmetric partners are taken to be extremely heavy. Members of the group have proposed a split supersymmetric model in the context of a universe with extra spatial dimensions.

The variation of the electroweak and strong interaction coupling constants with energy scale indicates that at very high energies one may have a unification of strong and electromagentic interactions. One promising candidate of such a Grand Unified Theory (GUT) is based on the gauge group SO(10). Members of the group have proposed an SO(10) GUT model which is consistent with experiments and can provide appropriate masses for the particles in the model.

In the context of strong interactions, color superconductivity in cold dense quark matter has been studied including the effect of t'Hooft six-fermion interactions which leads to an enhancement of the superconducting gap for light u and d quarks. BCS pairing of fermions has been further studied for different physical systems like cold fermionic atoms with mismatched number densities as well as in noncommutative quantum field theory. As with quark matter, different types of phases like BCS, breached pairing and LOFF phases seem to be possible depending on the coupling and mismatch in number densities for the case of cold atoms. Fermion condensates with finite momentum (LOFF phase) also arise in the case of noncommutative field theory which is driven by the scale associated with such a theory.

The observed spatial anisotropy in the cosmic microwave background radiation is consistent with a curvature power spectrum generated in the early universe by quantum fluctuations of a scalar field called the inflaton. If the initial state of the inflaton is taken to be a thermal state instead of the conventional zero particle vacuum state then the fluctuation spectrum of the microwave background radiation gets modified. This was compared with data obtained by the Wilkinson Microwave Anisotropy Probe to obtain a bound on the temperature of the inflaton.

In the nonlinear dynamics and complex systems area we have studied the stability of multicluster synchronized state using both linear stability and Lyapunov function approach. We find that when any two nodes are in driven synchronization, all the coupling terms in the difference between the variables of these two nodes cancel out whereas when they are in self-organized synchronization, the direct coupling term between the two nodes adds an extra term while the other couplings cancel out. We also suggest that the fluctuations of the conditional Lyapunov exponent about zero can be a criterion for the occurrence of floating nodes.

Synchronization properties of time varying networks depend on the topology of the network. If the different

Laplacians commute then the synchronized state for both the time-varying and the time-average topologies show similar stability properties. On the other hand for non-commuting Laplacians the time-varying topology shows in general better synchronization than the time-average topology.

Quantum chaos can be characterized using level fluctuations in random matrix models. Recently time series methods were used to relate the level fluctuations to the classical dynamics in the regular and chaotic limit. We show that the spectrum of the system undergoing order to chaos transition displays a characteristic f- noise and is correlated with the classical chaos in the system. We demonstrate this using a smooth potential and a time-dependent system modeled by Gaussian and circular ensembles, respectively, of random matrix theory.

Medium heavy nuclei (A ~ 60-100) with neutron number (N) close to proton number (Z) play crucial role in rapid proton capture nucleosynthesis and therefore there is considerable interest in both experimental and theoretical studies of these nuclei. Following recent demonstration of experimental possibilities, using a group theoretical model, predictions are made for deuteron transfer intensities between heavy even-even and odd-odd N=Z nuclei. Also solved completely is the representation theory for a fully fermionic group theoretical model for these nuclei. In addition, spectroscopic proprties of some heavy N=Z and N=Z+1 nuclei are studied by using a deformed shell model with isospin projection.

Using a new approximation to a terminating hypergeometric function of large arguments that we have recently obtained, we have derived a new expression in terms of the ordinary Bessel function for the quantum form factor for transition between circular Rydberg states. The expression is found to be accurate even for transitions involving low values of the principal quantum numbers.

Quantum Optics and Quantum Information

Entanglement or inseparability is one of the most striking features of quantum physics and is a great resource for the modern fields of quantum information and quantum computing. We have studied the inseparability of a special family of non-classical states, called the pair-coherent states which are non-Gaussian in nature. We confirmed the inseparability of pair-coherent states in the light of the Peres-Horodecki criterion and various entropies. We then demonstrated that the existing inseparability criterion based on second order correlation is applicable to this kind of non-Gaussian states only under certain constraints.

We have proposed a scheme to entangle two mesoscopic systems of the same type through a third mesoscopic system. In this context, we have also proposed a teleportation experiment in the mesoscopic setting using continuous variable entanglement for discrete variable teleportation. Among several bipartite entangled states, Werner states provide the simplest example of mixed states possessing entanglement. Experimentally, Werner states have been produced so far with only photonic qubits. We have proposed a scheme for generating Werner states with neutral atoms. The scheme is based on the collective decay dynamics of two atoms coupled coherently to a strong drive field. As the Werner states are obtained as steady state solutions of the decoherent dynamics, they are naturally stable and long lived. Furthermore, the proposal can be easily extended to trapped ions and is well within the realm of current experiments. We have also shown how ground-state coherences in a collection of atoms can be utilized for the generation of long lived mesoscopic superpositions and multiparticle entangled states. The striking feature of this work is the generation of the atomic entanglement via the interaction of a cold atomic sample with a single photon.

The generation of high intensity correlated photon source is a subject of current interest. The Stokes-anti-Stokes Raman emission doublet is such a source. We have calculated the two-photon intensity correlation between a pair of Stokes and Anti-Stokes photons, involving a sequential Raman emission process. We have shown that the correlation function shows photon anti-bunching feature and it also shows sinusoidal behavior with respect to time delay between the measurements of the two photons.

In the field of cavity QED, we have given a scheme for realizing quantum random walk in a cavity. We have shown that resonant interaction between atoms and the field in a high quality cavity can, as a consequence of quantum interference, produce quantum random walk. In this case, the field inside the cavity acts as a walker. Using a homodyne technique, the state of the quantum random walker can be monitored. We have also considered the effects of decoherence and the time scales at which the quantum nature of random walk survives.

Non-linear Schrödinger equation (NLSE) and its generalizations manifest in the description of Bose-Einstein condensates (BECs) as well as optical fibers with non-linearity. NLSE with a source arises in twin core optical fiber, as well as in the description of charge-density wave, plasma physics and many other physical problems. An exact mapping, based on fractional linear transform, is provided through which the solutions of the driven NLSE can be connected with elliptic functions. A wide variety of solitons including dark and bright ones are obtained as solutions.

A general procedure is provided to find the solutions to NLSE with time dependent coupling and a number of experimentally observed phenomena related to the solitons emerge from this analysis. The control of the motion of the solitons of the modified KdV equation is also achieved in the above manner. Through an exact treatment, it is shown that optical solitons can be effectively compressed through the manipulation of the time-dependent non-linearity parameter.

Revival and fractional revivals of quantum wave packets continue to be an area of active research. We have constructed the displacement operator coherent state of the Pöschl-Teller potential and studied its revival structure arising from different time scales underlying the quadratic energy spectrum of this system. We have also considered a one dimensional realization of the SU(2) coherent state for the Morse potential describing Hydrogen Iodide molecular wave packets. Using the Wigner function approach, we have shown that its fractional revivals can lead to sub-Planck scale structures in phase space. When rotational and vibrational motions are considered simultaneously, the revival dynamics of diatomic molecular wave packets become more involved. For heavy molecules such as I_2, the ro-vibrational coupling can be ignored, whereas for a light molecule such as H_2, they are strongly coupled.

In a controlled laboratory environment, we have studied the dispersion of smoke aerosols by using photon correlation techniques. The study will be useful in modeling the effect of atmospheric aerosols. The coherence properties of an optical vortex have been studied by measuring its Wigner distribution function by the use of a shearing Sagnac interferometer. Our experimental observations were in good agreement with the theoretical predictions.

Space and Atmospheric Sciences

Natural and anthropogenic aerosols have significant impact on regional climates. Studies of aerosols is a major thrust area of research at present. Investigations on the variation in aerosol physical properties during foggy and non-foggy conditions, were made as part of the ISRO-GBP land campaign conducted in the month of December at Delhi and Hisar. Lidar observations showed that during foggy condition there was a collapse in the vertical distribution of aerosols to a shallow height of about 200 m, which leads to an increase in the surface values of aerosol concentration by a factor of two to five. The higher surface humidity triggers hygroscopic growth of particles leading to an increase in the number concentration of the accumulation mode particles. All these effects result in an increase in the aerosol radiative forcing by about three fold.

In order to identify the sources of ozone and other related trace gases, continuous measurements of surface ozone, CO and NOx, twelve hourly sampling of air for analysis of NMHCs (Non -Methane Hydro Carbons) were done at Hisar and Kanpur under the ISRO GBP land campaign. These observations indicated that distribution of primary pollutants are controlled by biomass burning and biofuel combustion at both these places. During the same campaign, six balloons instrumented with sensors for ozone, temperature, water vapor, winds and GPS systems were flown from Kanpur to study the

tropospheric ozone content. It was found that on one of these days the average tropospheric content, which on an average is around 45 DU, far exceeded this value and became 54 DU. Based on the ECMWF potential vorticity data, it was shown that this large increase in tropospheric ozone content was due to the intrusion of stratospheric ozone.

A study of large number of space weather events was carried out using the Indian MST and VHF radars, PRL's 630 nm photometers and Advanced Composition Explorer (ACE) satellites data on z-component of the interplanetary magnetic field, Bz and y-component of the interplanetary electric field, IEFy. This study brought out the importance of sudden turning of the interplanetary magnetic field Bz, the eastward electric field and the seed perturbation in the development of the equatorial spread F irregularities.

Modeling of the ions in the inner coma of comet Halley was performed using the measured densities of major neutral species by Giotto spacecraft, solar EUV photons, photoelectrons and solar wind electrons as ionizing sources and an analytical yield spectrum model. The calculated ion densities, in the mass range of 10-40 amu, in 1500 -6000 km altitude range, were in very good agreement with the values measured by the Giotto ion mass spectrometer.

The momentum spectrometry experiment has yielded intrigueing results regarding the rearrangement of atoms/ions during dissociative ionization of a large molecule like ethanol. It was shown that atoms migrate from their sites in the neutral molecule to form bonds with atoms at other sites. The rearrangement makes the molecule unstable, thereby creating unusual molecular ions. For example H_3^+ and H_2^+ are found to be formed from C_2H_5OH by the rearrangement of H atoms initially at the oxygen and carbon sites, even though the equilibrium distances between these atoms are large.

Velocity profiles of laser produced plasmas were found to depend not only on the atomic mass of the target, but also on the ambient pressure. At low ambient pressures, the expansion velocity decreases with increasing mass, and the behavior is explained by a drag model. At higher pressures, reverse trend was observed. Contrary to expectation, the ejected material did not homogenize at high ambient pressures; this nature is explained by a shock model.

Planetary and Geosciences

Research carried out in the Planetary and Geosciences Division covers areas related to the early evolution of the Sun and solar System objects and diverse aspects of earth system sciences.

Lithium isotopic studies in Ca-Al-rich inclusions (the earliest solids formed in the solar system) from primitive carbonaceous chondrites did not confirm the excess in ^{7}Li, reported earlier by US-France groups who have interpreted the excess as a decay product of the extremely short-lived (half-life = 65 days) ^{7}Be, attributed to be formed by solar cosmic ray irradiation. Our negative result shows that the case for solar origin of short lived nuclides is yet to be confirmed and favours a stellar source.

Past variations in the south Asian summer monsoon have been inferred earlier mainly using wind proxies in marine sediment cores from the upwelling-dominated western Arabian Sea. We measured precipitation proxies, i.e., high-resolution stable oxygen isotope variations of three different species of planktonic foraminifera in an AMS ^{14}C dated sediment core from the monsoon-runoff-dominated eastern Arabian Sea. A comparison of the above data sets reveals that during the past ~2800 years reductions in monsoon wind strength in the western Arabian Sea were persistently accompanied by aridity over India, significantly influencing post-Harappan cultures.

We have carried out an extensive noble gas study in Indian carbonatites in an attempt to obtain insight into the origin of carbonatitic volcanism. Our study has revealed that noble gases in carbonatites are a mixture of trapped and in situ produced components. In the case of younger carbonatites of Ambadongar and Sung Valley, the in situ component is very minor, allowing further resolution of trapped component (for He, Ne) into those of depleted mantle (DM) and an admixture of a lithospheric mantle component, introduced during some ancient sub-

duction process. However, Ar and Xe isotopic signatures together indicate a less depleted mantle (LDM) component, suggesting decoupled behaviour of light and heavy noble gases. South Indian carbonatites on the otherhand reveal an LDM component and an overwhelming contribution from an enriched lithospheric mantle. The Indian carbonatites studied here seem to have been generated during the waning stages of plume magmatism leading to considerable DM and lithospheric mantle inputs as the uprising deep magma induces their melting and subsequent entrainment.

The Sr and Nd isotope composition of sediments of the Ganga and the Brahmaputra rivers show that the Higher Himalaya is the primary source for these sediments and that the Himalaya is undergoing differential erosion. It is seen that basins with high relief such as the Gandak in the Ganga Basin and the Eastern Syntaxis of the Brahmaputra are eroding very rapidly at rates of ~6 and 14 mm/y respectively compared to other regions of these basins which have erosion rates of ~2 mm/y. Such rapid erosion in these areas is causing rapid uplift resulting in the high peaks of the Namche Barwa, the Dhaulagiri and the Annapurna.

Aerosols act as a transport path for water-soluble organic compounds (WSOC) to the atmosphere, transforming the surface layer of aerosols from hydrophobic to hydrophilic and resulting in pronounced influence on their chemical and optical properties and radiation balance of the atmosphere. Concentrations of water-soluble inorganic ions, organic compounds and total organic carbon were measured in bulk-aerosols collected on daily basis, during winter from an urban-site in North India. Both WSOC and OC exhibit statistically significant positive correlation with potassium but exhibit weak covariance with sulphate; suggesting that their abundances are dominated by local biogenic source (biomass burning) with insignificant contribution from anthropogenic sources.

PLANEX

The design and development of the high energy X-ray (HEX) spectrometer is being carried out jointly by the PLANEX group at PRL and SAID at ISAC, Bangalore. HEX will measure low energy (30-270 keV) emissions from the lunar surface to quantitatively understand the transport of volatiles on Moon. PRL is responsible for developing the detector module, front-end-electronics (FEE), detector characterization, and integration of the final payload with help from SAC, Ahmedabad. Various circuits of FEE for the HEX payload have been designed, and successfully interfaced with the CZT detector. A Ground Checkout System for checking the performance of FEE coupled to the CZT detector has also been developed and the results of the check-test performed match predefined specifications of the HEX spectrometer.

Computational Facility

PRL provides state of the art computational facilities to all the members. There is a central computing facility consisting of several high power servers. New servers are added every year. Recently we have added six xenon servers to this pool. The facility is connected to internet through a dedicated 1 MBPS link. The process of installing a high performance computing cluster has been initiated. PRL plans to join the national GRID computing facility - GARUDA, which is a joint venture of C-DAC and ernet. The central computing facility is connected to individual PCs through LAN connecting all buildings by fibre cable spread over about a kilometer with gigabit and 100 Mbps switches. Every member has an access to a PC with each faculty member having an individual PC. In addition, there are several PCs in the computer centre for visitors and students.

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**). In addition, PRL also has an Associateship programme meant for University teachers for making short-term visits to work in collaboration with the faculty. This provides them with an opportunity to use experimental, computing and library facilities to pursue their research work.

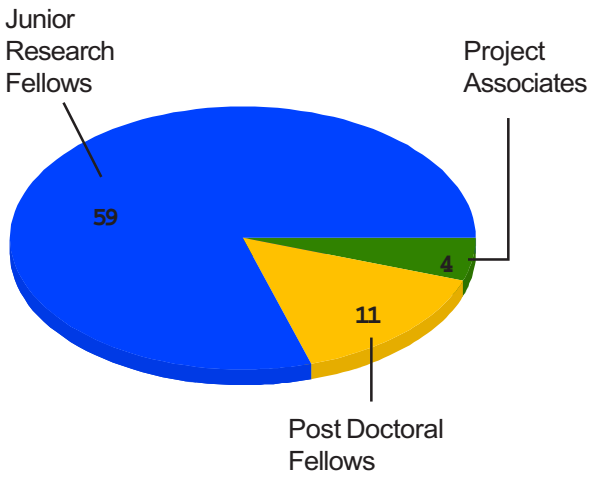


Fig. 1 Doctoral, Post Doctoral and other Programmes

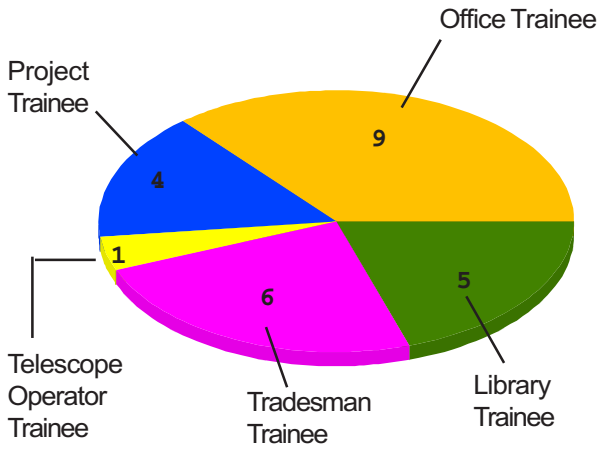


Fig. 3 Training Programme at PRL

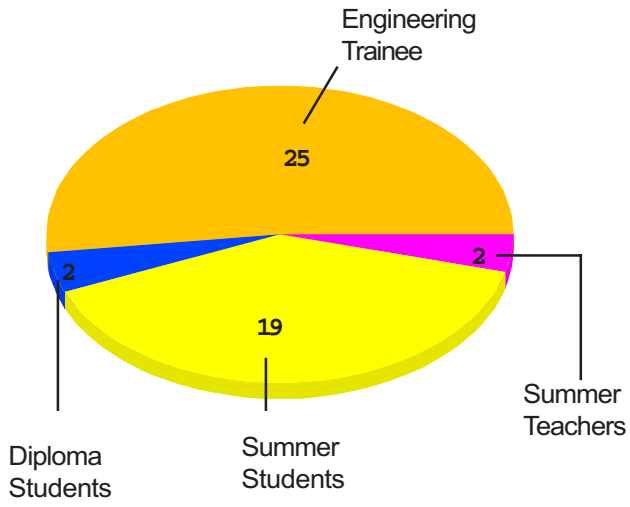


Fig. 2 Graduate & Post Graduate Programme

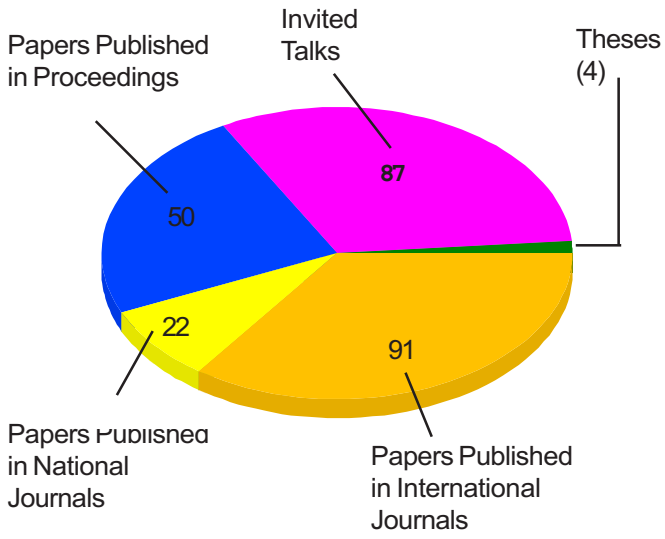


Fig. 4 Scientific Output of PRL

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 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. Our scientists are also invited to write review articles in books and journals in the fields 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 such 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 scientists convened the following :

1. Space Weather Effects in Ionosphere, IAGA Scientific Assembly, July 18 - 29, 2005**,** Toulouse, France.
   (Co - conveners: S. P. Gupta and H. Chandra)

2. 6th PLANEX Workshop on Remote Sensing and Chandrayaan-1 Mission, October 23 - 28, 2005, NRSA, Hyderabad.
   (Conveners: J. N. Goswami, PRL, A. Senthil Kumar, NRSA and G. Parthasarathy, Scientist, NGRI)

3. Ionospheric Effects in Radio Communications, XXVIII General Assembly URSI, October 23-29, 2005**,** NPL, New Delhi.
   (Co - conveners: S. P. Gupta and H. Chandra)

4. One Day Workshop on Thirty years after Dhajala Meteorite Shower: Progress in Planetary Sciences, January 29, 2006; PRL, Ahmedabad.
   (Convener: J.R. Trivedi)

5. International Symposium on Quaternary Studies, March 2-3, 2006, PRL, Ahmedabad.
   (Convener: A.K. Singhvi)

6. PLANEX Workshop on Remote Sensing and Chandrayaan-1 Data Analysis, March 6-7, 2006, PRL, Ahmedabad.
   (Convener: D. Banerjee)

7. XXI SERC Main School in Theoretical High Energy Physics, February 11 - March 3, 2006, PRL, Ahmedabad
   (Course Director : R. Rangarajan)

Distinguished Visitors at PRL

Prof. Satish R. Shetye, Director, National Institute of Oceanography, Goa visited PRL and delivered the twenty first Prof. K. R. Ramanathan Memorial Lecture on *The Indian Summer Monsoon & the North Indian Ocean*.

Shri G. Madhavan Nair, Secretary, DOS / Chairman, ISRO, Govt. of India visited PRL and delivered an address on the *Department of Space and its Future*.

The **Year of Physics-2005**, marking the hundredth year of publication of Einstein's three seminal papers on Photoelectric Effect, Brownian Motion & Special Relativity that changed the course of physics in the twentieth century, was celebrated world over by holding conferences, seminars, lectures and exhibitions on the life and work of Albert Einstein. PRL also organized a number of popular lectures as well as technical seminars by scientists from within and other institutions during this year. Sixteen lectures were planned under the auspices of this program during August-December 2005, of which five are public lectures. Some of the important public lectures that have been delivered are **Prof. P.C. Vaidya**'s talk on *Einstein's Universe*, **Prof. J.V. Narlikar**'s on *Cosmology in the Post-Einstein Era,* **Prof. C. V. Visheshwara's** on *Cosmos and Culture* and **Prof. S. Dattagupta's** on *Brownian Motion*.

A **ten year review** of the laboratory's scientific activities was held in the months of February and March 2005. There were different committees for different subjects. Eminent scientists from India and abroad were members of the committee. They were **Profs. P. Lena, J. Veizer, A. Halliday, J. Lelieveld, E. Ma, A. P. Mitra,**

P. C. Agrawal, P. Rao, M. S. Srinivasan, N. Mukunda and N. Kumar. The members also interacted with the faculty and had extensive discussions with them.

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 were 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	40

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

As a part of implementation and progressive use of Hindi in PRL, the **Hindi Pakhwada** was celebrated at PRL from September 14 - 28, 2005. The highlights of the celebrations included word quiz, essay writing, elocution, Hamara Karya, self written poetry competitions. The celebration was inaugurated by **Prof. Raghuveer Chaudhury**, former Head, Hindi Department, Gujarat University and an eminent writer in Hindi and Gujarati.

PRL conducted a **One Day Seminar in Hindi on Contribution of PRL in the Field of Science & Technology** on March 24, 2006, in which eleven speakers were invited. The key note address was delivered by Prof. J.N. Goswami, Director, PRL. Shri B.S. Bhatia, Director, DECU, SAC, Ahmedabad inaugurated the seminar and delivered the inaugural address on *Hamari Vaigyanik Virasat Aur Naya Sandarbh*.

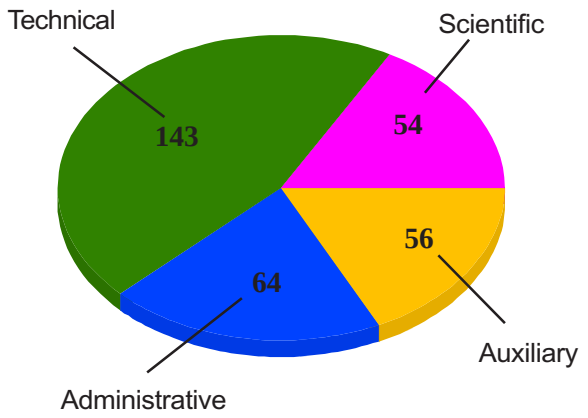


Fig. 5 Staff Structure of PRL

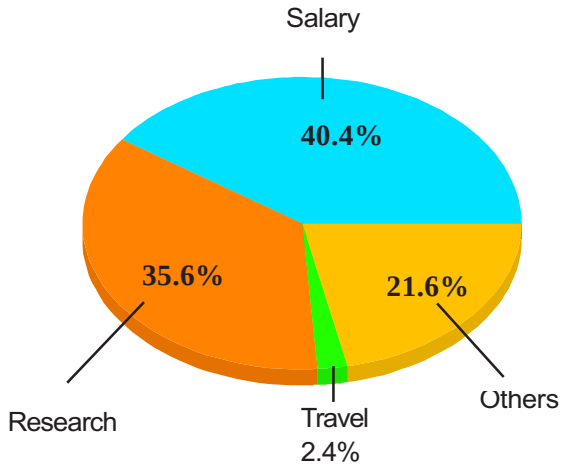


Fig. 6 Budget of PRL

In addition, PRL personnels also participated in **DOS Inter Centre Technical Seminar in Hindi**, held at ISAC, Bangalore during 25-26 November, 2005 in which four papers on various topics were presented.

On the occasion of the *Foundation Day of PRL*, **Prof. S.P. Pandya** delivered a popular lecture on *Dr. Vikram A. Sarabhai*. In addition lectures highlighting the *Nobel Prize in Physics for the year 2005* were delivered by **Dr. P. K. Panigrahi** and **Dr. Dilipkumar Angom**, both from PRL.

PRL celebrated the **National Science Day**, in association with the Indian Physics Association (IPA),

Ahmedabad Chapter on February 25, 2006. Teachers and students from more than two ninety schools from all over Gujarat participated in this event that comprised of science quiz, both written and oral, for students of Stds. IX and X, popular lectures, exhibition and interactive quiz for the teachers. The interactive open quiz was on Nurture Nature for the Future. Further highlights of the celebration included talks on *Water Management* by **Dr. Apurva Oza**, CEO, Agha Khan Rural Support Programme (India) and movies on Nanotechnology and Water and Environment related topics. In addition, the Centre for Environmental Education organized an exhibition and puppet show on *Prakriti*.

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 they continue to study in science stream with high academic record.

Awards and Honours

Prof. U. R. Rao has been

i. Appointed Chairman of the Karnataka Science & Technology Academy, Karnataka.

ii. Awarded the Theodore Von Karman Award of the International Academy of Astronautics, Paris, France.

iii. Awarded the D. Sc. (Hons. Causa) from the UP Technical University, Lucknow.

iv. Appointed Chancellor, Babasaheb Bhimrao Ambedkar University, Lucknow.

v. Awarded the D.Sc. (Hons. Causa) from the Viswesvaraiah Technical University, Belgaun, Karnataka.

Prof. J. N. Goswami has been nominated as a Council Member of the Indian Space Research Organization, Bangalore and of the Institute for Plasma Research, Gandhinagar.

Prof. G. S. Agarwal has been

i. Offered the TEES Research Professor of Quantum Studies, Texas A & M University.

ii. Invited to serve on the NSF panel on quantum computing and emerging technologies

iii. Invited to serve on the board of Optics Communications for another period of three years.

iv. Invited to be the Moderator for the Optics section of the ARXIV.

Prof. S. Lal has been awarded the Astronautical Society of India Award for the year 2003 in Space Science & Applications.

Prof. A. Jayaraman has been elected Fellow of the Indian Academy of Sciences, Bangalore.

Prof. S.K. Bhattacharya has been elected Fellow of the National Academy of Sciences, Allahabad.

Prof. A.K.Singhvi has been

i. Elected to the Council of the Indian National Science Academy and of the Geological Society of India

ii. Invited to be on the Editorial boards of the Journals: Quaternary Research, The Holocene and Journal of Quaternary Science.

Pof. S.V.S. Murty has been conferred the *Eminent Massspectrometrist Award* by the Indian Society for Mass Spectrometery.

Prof. R. Ramesh has been invited to join the editorial boards of the Journal of Earth System Science and the Indian Journal of Marine Sciences.

Dr. J.S. Ray

i. has been the recipient of the BOYSCAST Fellowship from DST, Government of India.

ii. has edited a special issue of Journal of Earth System Science (Indian Academy of Sciences) on Vindhyan Geology (Volume 115, Issue 1, 2006).

Dr. N. Juyal has been invited to be a member of the National Working group of IGCP-500 on Drylands.

Mr. Satya Prakash won the prestigious SCOR-POGO fellowship 2005-06, offered through international competition.

Dr. J. Banerji

i. Cover page illustration of Applied Optics, 44, 16 (1June, 2005) was from the paper on "Phased array 1-to-N-way resonator with a convex mirror for phase conjugation", by J. Banerji, A. R. Davies, and R. M. Jenkins

ii. Cover page illusration of J. Phys. B: At. Mol. & Opt. Phys., 39, Issue 5, (14 March 2006) was from the paper "The role of ro-vibrational coupling in the revival dynamics of diatomic molecular wave packets", by J. Banerji and S. Ghosh.

Best Presentations & Posters

Dr. Manish Tiwari won the first prize in the Research Scholars' oral Presentation at the "10th ISMAS Triennial International Symposium on Mass Spectrometry" held at Munnar, India, during January 28 to February 1, 2006.

The paper entitled "Spectral Reflectance studies of Copernicus and Tycho craters on Moon" by **Neeraj Srivastava** was adjusted the best paper presented at the NSSS-2006 held at Vishakhapatnam during 9-12 February 2006.

R. Rengarajan, Sunil K. Singh and M.M. Sarin, have received the best poster award for the poster "Major Ion and Sr Isotope Composition of Source Waters of the Chambal River", presented at the "10th ISMAS Triennial International Symposium on Mass Spectrometry" held at Munnar, India, during January 28 to February 1, 2006.

Books/Monographs/Reviews Published in 2005-06

Books/Monographs

1. B.G. Anandarao and D.P.K. Banerjee, Guest Editors for Proceedings of the National Symposium on Infrared and Optical Astronomy from Mt. Abu Observatory, Special Volume of *Bull. Astron. Soc. India*, June (2005).

2. Dr. J.S. Ray, Edited a special issue of *Journal of Earth System Science (Indian Academy of Sciences) on Vindhyan Geology* , **115**, 1, (2006).

Review Papers

3. B.G. Anandarao, "Spatio-Kinematic studies of galactic planetary nebulae", *special volume on 21st Century Astrophysics*, e ds: S.K. Saha and V.K. Rastogi, *Asian. J. Phys.*, pp. 134-148 (2005).

4. Boss A.P. and Goswami J.N., "Presolar cloud collapse and the formation and early evolution of the solar nebula", in *Meteorites and the Early Solar System II* (Ed. D.S. Lauretta and H.Y. McSween Jr.), University of Arizona Press, pp171-186 (2006).

5. J. N. Goswami, K. K. Marhas, M. Chaussidon, M. Gounelle and B. Meyer, "Origin of short-lived radionuclides in the early solar system", in *Chondrules and the Protoplanetary Disk* (Ed. A. N. Krot, E. R. D. Scott and B. Reiputh), pp. 485-514, ASP Publ., **341**, (2005).

Papers Published in Journals in 2005-06

Astronomy and Astrophysics

1. D.P.K. Banerjee, R.J. Barber, N.M. Ashok, J. and Tennyson, "Near-infrared water lines in V838 monocerotis", *ApJ*, **627**, L141-L144 (2005).
2. S.K. Chakrabarti, B.G. Anandarao, S. Pal, S. Mondal, A. Nandi, A. Bhattacharyya, S. Mondal, R. Sagar, J.C. Pandey, A. Pati and S.K. Saha, "SS 433 : Results of a recent multiwavelength campaign", *MNRAS*, **362**, 957-965 (2005).
3. A.C. Gupta and U.C. Joshi, "Intra-night optical variability of luminous radio-quiet QSOs", *A&A*, **440**, 855-865 (2005).
4. M. Bottcher, J.Harvey, K.S.Baliyan et al., "Coordinated multiwavelength observation of 3C 66A during the WEBT campaign of 2003-2004", *Ap.J.*, **631**, 169-186 (2005)
5. P. Janardhan, K. Fujiki, M. Kojima, M. Tokumaru, and K. Hakamada, "Resolving the enigmatic solar wind disappearance event of 11 May 1999", *J. Geophys. Res.*, **110**, 08101J (2005).
6. U.S. Kamath, G.C. Anupama, N.M. Ashok, Y.D. Mayya and D.K. Sahu, "Optical and near-infrared spectroscopy of Nova V1494 Aquilae 1999 no. 2", *MNRAS*, **361**, 1165-1172 (2005).
7. S. Mondal and T. Chandrasekhar, "Angular diameter measurements of evolved variables by lunar occultations at 2.2 and 3.8 Microns", *AJ*, **130**, 842 -852 (2005).
8. N.M. Ashok, D.P.K. Banerjee, W.P. Varricatt, and U.S. Kamath, "Near-infrared and optical studies of the fast Nova V4643 Sgr (Nova Sagittarii 2001)", *MNRAS*, **368**, 592-598 (2006).
9. G. Koshy, D.P.K. Banerjee, T. Chandrasekhar and N.M. Ashok, "A late infrared flash from the afterglow of GRB 050319", *ApJ*, **640**, L13- L16 (2006).
10. Hari Om Vats, S.P. Bagare and S.M. Bhandari, "Formation and observations of shadow bands during the total solar eclipse of 23 November 2003 near Maitri,Antarctic", *Advances in Geosciences*, 2, 364-371, 2006.
11. W.P. Varricatt and N.M. Ashok, "WR 143: a Wolf-Rayet binary", *MNRAS*, **365**,127-133 (2006).
12. A. Richichi and T. Chandrasekhar, "Near-infrared observations of the Carbon stars TU Geminorum and SS Virginis at milliarcsecond resolution", *A&A*, **451**, 1041-1044 (2006).
13. C. Mercier, P. Subramanian, A. Kerdraon, M. Pick, S. Ananthakrishnan and P. Janardhan, "Combining visibilities from the Giant Meterwave Radio Telescope and the Nancay Radio heliograph High Dynamic Range Snapshot Images of the solar corona at 327 MHz", *A&A*, **447**, 1189-1172 (2006).

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14. Nandita Srivastava, "The challenge of predicting the occurrence of super-storms", *Annales Geophysicae*, **23**, 2989 - 2995 (2005)
15. Nandita Srivastava, "Logistic regression model for predicting the occurrence of major geomagnetic storms", *Annales Geophysicae*, **23**, 2969-2974 (2005)
16. P. Venkatakrishnan, R. Sridharan, and S.K. Gupta, "Imaging with insolated mirrors", *BASI,* **33**, 265-274 (2005)
17. Sanjay Gosain, P. Venkatakrishnan, and K. Venugopalan, "Design of instrument control software for solar vector magnetograph at Udaipur Solar Observatory", *Experimental Astronomy*, **18**, 31-38 (2006)
18. A. Ambastha, B. Ravindra and S. Gosain: "H-alpha observations of 8 June, 2004 Venus transit", *Solar Phys.*, **233**, 171-184 (2006)

Theoretical Physics and Complex Systems

High Energy and Astroparticle Physics

19. B. Ananthanarayan and S.D. Rindani, "New physics in $e^+e^- \to Z\gamma$ with polarized beams", *JHEP*, **10**, 077 (2005).
20. B.R. Desai, G. Rajasekaran and U. Sarkar, "An SO(10) GUT with see-saw masses for all fermions", *Phys. Lett. B* **626**, 167-174 (2005).

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23. S. Mohanty, A.R. Prasanna and G. Lambiase, “Scale invariant leptogenesis from spin-gravity coupling following inflation”, *Phys.Rev.Lett.*, **96**: 071302, (2006).

24. K. Bhattacharya, S. Mohanty, R. Rangarajan, “Temperature of the inflaton and duration of inflation from WMAP data”, *Phys.Rev.Lett.*, **96**:121302, (2006).

25. J. Bhatt and R. Rangarajan, “Studying electroweak Baryogenesis using Evenisation and the Wigner Formalism”, *JHEP*, 0503, 057 (2005).

Nonlinear Dynamics and Complex Systems

26. S. Jalan, R. E Amritkar and C. K. Hu, “Synchronized clusters in coupled map networks I. Numerical studies”, *Phys. Rev.*, **E 72**, 016211-1--15 (2005).

27. R. E Amritkar, S. Jalan and C. K. Hu, “Synchronized clusters in coupled map networks II. Stability analysis”, *Phys. Rev.*, **E 72**, 016212-1-9 (2005).

28. M. S. Santhanam and J. N. Bandyopadhyay, “Spectral fluctuations and 1/f noise in the order-chaos transition regime”, *Phys. Rev. Lett.*, **95**, 114101 (2005).

29. R. E. Amritkar and C. K. Hu, “Synchronized state of coupled dynamics on time-varying networks”, *Chaos*, **16,** 015117 (2006).

30. M. S. Santhanam, Jayendra Bandyopadhyay and Dilip Angom, “Quanrum spectrum as a time series : Fluctuation measures”, *Phys.Rev. E* (Rapid Comm) : 015201(R), (2006).

Atomic and Nuclear Physics

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High Energy and Astroparticle Physics

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Theses Submitted during 2005-06

1. **N. Rastogi**

   Environmental Radionuclides and Chemical Constitutes in Rain and Aerosols : Biogeochemical Sources and Temporal Variations (2005).

2. **H. Gadhavi**

   Experimental Investigation of Aerosol Properties and Modeling of its Impact on Radiation Budget (2005).

3. **Manoj Jaiswal**

   Optically Stimulated Luminescence Dating of Fluvial Sediments : Applications and Implications of Paleoseismology (2005)

4. **T. Sreecharan**

   Studies in Noncommutative Field Theories (2005).

M. Tech. Thesis Submitted

1. **Kota Uma**

   "Multi Wavelength Studies of Mesospheric and Lower Thermospheric Airglow Emissions " (2005).

Technical Report

1. **Sanjay Gosain**

   "Interactive Image Acquisition and Display Program FLAREVISION for Image Point CCD Camera" (2005).

Invited Talks Presented in Symposia/Schools in 2005-06

Astronomy and Astrophysics

Hari Om Vats

1. "Geo-effectiveness of the solar wind extremes", at *International Solar Physics Workshop*, Aryabhatta Research Institute (ARIES), **Nainital**, India, April 6, 2005.
2. "Formation and observations of shadow-bands", *Asia Oceania Geosciences Society Meeting*, Suntec city, **Singapore**, June 20 - 24, 2005.
3. "Geo-effectiveness of the solar wind extremes", at *International Solar Physics Workshop*, Aryabhatta Research Institute (ARIES), Nainital, India, April 6, 2005.

P. Janardhan

4. "Locating the solar source of the extremely low-density, low-velocity solar wind flows of 11 May 1999", at the *ILWS Workshop on The Solar Influence on the Heliosphere and Earth's Environment: Recent Progress and Prospects*, **Goa**, India. February 19-24, 2006.

B.G. Anandarao

5. "Science Programmes with an imaging Fabry-Perot Spectrometer", at *Indo-French Astronomy Network: Prospects and Programmes*, held at IUCAA, **Pune**, during 30 June - 1 July 2005.

Solar Physics

Ashok Ambastha

6. "Evolution of magnetic and velocity fields in super-active region NOAA AR 10486 and the large 4B/X17.2 Class flare observed during October 28, 2003" at the *IHY2006 Annual Meeting of the Balkans, Black Sea and Caspian Sea Regional Network on Space Weather Studies*, Manavgat-Antalya, **Turkey**, March 20-April 1, 2006.

Nandita Srivastava

7. "Can solar parameters improve the space weather prediction?", at the *Indo-Chinese Workshop*, **Bangalore**, November 7-11, 2005.
8. "The challenge of predicting the occurrence of intense storms" at the *National Space Science Symposium*, **Vishakhapatnam**, February 9-12, 2006.
9. "Role of solar and interplanetary parameters in the prediction of occurrence of geomagnetic storms", at the *International Living With a Star (ILWS) Workshop*, **Goa**, Feb 19-24, 2006.

Sanjay Gosain

10. "Design and status of solar vector magnetograph at Udaipur Solar Observatory", at the *International Solar Workshop on Transient Phenomena on the Sun and Interplanetary Medium*, held at ARIES, **Nainital**, April 05-07 April 2005.
11. "Observing facilities and instrumentation at Udaipur Solar Observatory", at the *Indo-Chinese Workshop* held at IIA, **Bangalore**, November 7-11, 2005.

Shibu K. Mathew

12. "Polarimeter for MAST at USO", at the *Indo-Chinese Workshop* held at IIA, **Bangalore**, November 7-11, 2005.
13. "Umbral core brightness variation with solar cycle", at the *International Living With a Star (ILWS) Workshop*, **Goa**, Feb 19-24, 2006 .

P. Venkatakrishnan

14. "Dynamics of active region magnetic fields"", at the *Indo-Chinese Workshop* held at IIA, **Bangalore**, November 7-11, 2005.
15. "Space weather science and applications: Road Map for Solar Physics", at the *National Space Science Symposium,* **Vishakhapatnam**, February 9-12, 2006.

Solar X-ray Astronomy and Submillimeter Science

Hemant Dave

16. "Submillimeter wave science and technology at PRL and future plans", at *ALMA Detector Workshop*, NAOJ, Mitaka, **Japan**, March 8, 2005.

17. "Submillimeter wave balloon born experiment PRL-LERMA collaborative proposal", at ***Indo-French Astronomy Network : Prospects and Programmes***, **Pune,** June 30 - July 1, 2005

18. "Submillimeter Wave Science and Applications", at *XXVIIIth General Assembly of International Union of Radio Science*, NPL, **New Delhi**, October 23-29, 2005.

19. "Submillimeter/Terra Hertz Science from Moon", at the I*nternational Lunar Organization Workshop*, Kona, **Hawaii**, November 17-20, 2005.

20. "Observation and analysis of submillimeter spectral lines from dark, quiescent clouds", at *14th National Space Science Symposium,* **Visakhapattanam**, 9-12 February 2006.

Rajmal Jain

21. "Solar X-ray Spectrometer (SOXS) mission - low energy payload - first results", at *International Solar Workshop on Transient Phenomena on the Sun and Interplanetary Medium* held at ARIES, Nainital, **India** during 05-07 April, 2005.

22. "Solar X-ray Spectrometer (SOXS) mission - first space-borne solar astronomy experiment of India", at *Indo-Chinese Workshop on Recent Advances in Solar Physics* held at Indian Institute of Astrophysics, Bangalore, **India** during 07-11 November 2005.

23. "Discoveries from the Solar X-Ray Spectrometer (SOXS) mission onboard GSAT-2 Indian spacecraft", at *XIV National Space Science Symposium (NSSS-2006)* held at Dept. of Physics, Andhra University, **Visakhapatnam** during 09-12 February 2006.

24. "Solar X-ray Spectrometer (SOXS) mission: observations and new results", at *ILWS Workshop on The Solar Influence on the Heliosphere and Earth's Environment: Recent Progress and Prospects*, held in **Goa**, **India**, during February 19-24, 2006.

Theoretical Physics and Complex Systems

S. D. Rindani

25. "New physics at linear collider with polarized beams", at the *National Conference on 2005, Exciting Physics of this Decade*, Dept. of Theoretical Physics, University of Madras, **Chennai,** December 2-3, 2005.

26. "Physics prospects at a linear collider", at the *9th Workshop on High Energy Physics Phenomenology (WHEPP9)*, January 3-14, 2006, **Bhubaneswar**.

U. Sarkar

27. "Models with extra dimensions, in Fireball", *Workshop in High Energy Physics Phenomenology*, HRI, **Allahabad**, July 2005.

28. "Models of neutrino masses and leptogenesis", in *Dark Energy Workshop*, Ludwig Maxwellian University, Munich, **Germany**, Oct 10-15, 2005.

R. E. Amritkar

29. "Introduction to nonlinear dynamics", **12 lectures** at the *SERC School on Nonlinear Dynamics*, University of Pondicherry, **Pondicherry**, 4-7 January 2006,.

30. "Control of chaos and synchronization", *National Conference on Nonlinear Systems and Dynamics*, University of Madras, **Chenna**i, February 6-8, 2006.

V. K. B. Kota

31. "Group symmetries and solvable models in nuclear structure", *National Conference on Exciting Physics of this Decade*, held at University of Madras, **Chennai** (India) during December 2-3, 2005.

32. "Statistical spectroscopy methods for level densities and GT strengths in nuclear astrophysical applications", *School-cum-Workshop on Low Energy Nuclear Astrophysics* held at Saha

Institute of Nuclear Physics, **Kolkata**, during January 16-20, 2006.

D. P. Dewangan

33. "Quantum Mechanical approach to Rydberg transitions", *International Conference on Current Developments in Atomic, Molecular and Optical Physics With Applications* (CDAMOP), Delhi University, **Delhi**, March 21-23, 2006.

34. "Thermal QCD sum rule for charmonium", in *Workshop on Supercomputing RHIC physics*, TIFR, **Mumbai**, December 5-9, 2005.

D. Angom

35. "Quantum Many-Body Chaos in Lanthanide Atoms", *National Conference on Nonlinear Systems and Dynamics*, RIASM, **Chennai,** February 6-8, 2006.

Quantum Optics and Quantum Information

G. S. Agarwal

36. "Manipulation of the Decoherence of Quantum States", in *Frontiers of Quantum Optics and Applications*, Max-Planck Institute for Quantum Optics, **Germany**, April 19 - 20, 2005.

37. "Quantum Entanglement from Collective Decay in Coherently Driven Atoms", in *International Conference on Uncertainty Relations and Squeezed States*, **France**, May 2-6, 2005 [presented by A Gabris on behalf of G. S. Agarwal]

38. "Non classical Radiation from Two Atoms and Quantum Search Algorithms", in *International conference on quantum optics*, **Hong Kong**, December 16 - 20, 2005.

39. "Cavity-mediated long-range interaction for fast quantum logic and quantum entanglement", in *Conference on Quantum Computing : Back Action*; Indian Institute of Technology, **Kanpur**, India, March 6 - 12, 2006.

40. "Coherent Control of Matter Wave Solitons in BEC", in *2nd International Conference on Current Developments in Atomic, Molecular & Optical Physics with Applications*, Delhi University, **India**, March 21 - 23, 2006.

P. K. Panigrahi

41. "Non-destructively discriminating orthogonal entangled states", *Conference on Quantum Computing : Back Action*; Indian Institute of Technology, **Kanpur**, India, March 6 - 12, 2006.

42. "Coherent control of matter wave solitons in Bose Einstein condensates", *2nd International Conference on Current Developments in Atomic, Molecular & Optical Physics with Applications*, Delhi University, **India**, March 21 - 23, 2006.

43. "Modeling of financial time series", *International workshop on Econophysics of stock markets & minority games*, **Kolkata**, February 14 - 17, 2006.

B. Deb

44. "Quantum correlation in Bose-Einstein condensate and Fermi superfluid of atomic gases", in *Topical Conference on Atomic Molecular and Optical Physics,* Indian Association for the Cultivation of Science, **Kolkata**, December 13 - 15, 2005.

Space and Atmospheric Sciences

A. J ayaraman

45. "Indian campaigns for aerosol studies during 2004", *ABC Science Team Meeting*, UNEP-Tongji Institute, Shanghai, **China**, April 4-6, 2005 .

46. "Monsoon Asia Integrated Regional Study-Outline and present status and IGAC-Atmospheric Brown Cloud Task", at the *IGAC SSC meeting*, Santiago, **Chile**, October 11-14 2005.

47. "Aerosols and Climate: An Emerging Understanding of the South Asian Region", *Asian Aerosol Conference*, **Mumbai**, December 13-16, 2005.

48. "Atmospheric aerosols and trace gases studies under the ISRO-GBP - Results and Priorities", *National Space Science Symposium*, Andhra Univ., **Visakhapatnam**, February 9 -12, 2006.

49. "Our present understanding on aerosols and aerosol radiative forcing over the south Asian Region", *IGBP Workshop on Global Change*, IITM, **Pune**, March 3, 2006.

50. "Aerosols and Aerosol Radiative Forcing over India - Results, Issues and Priorities", *INDO-UK Workshop on Earth Observations for Weather and Climate*, SAC, **Ahmedabad**, March 28-30, 2006.

S. Lal

51. "Trace Constituents and Environment", *IMS Pune Chapter,* IITM, , Pune, July 21, 2005.

52. "Atmospheric chemistry over the Indian region", *APN Workshop*, Beijing University, Beijing, **China**, November 21, 2005.

53. "Recent developments in atmospheric science", National Seminar on Recent Advances in Condensed Matter and Space Physics, Saurashtra, Univ., **Rajkot**, March 21, 2006.

54. "Study of trace gases and their role in climate change", *Indo-UK Workshop*, SAC, **Ahmedabad,** March 28-30 2006.

S. Ramachandran

55. "Atmospheric Aerosols : Impact on Radiative Forcing & Climate Change", at *National Space Science Symposium*, Andhra University, **Visakhapatnam**, February 9-12, 2006.

H. Chandra

56. "Applications of CRABNET", at *CRABEX User Workshop*, SPL, VSSC, **Trivandrum**, January 17-19, 2006 .

57. "Ionospheric Physics and Ionospheric Turbulence", *Workshop on Space Weather*, Pune University, **Pune**, March 1-3, 2006.

58. "Space weather", *National seminar on Recent Advances in Condensed Matter and Space Physics*, Saurashtra University, **Rajkot**, 21 March 2006.

59. "Space weather", *Workshop on Space Weather,* **3 lectures**, **Pune**, 1-3 march 2006.

H. S. S. Sinha

60. "Space Education in India", at *12th Asia Pacific Regional Space Agency Forum*, Japan Aerospace Exploration Agency, Kitakyushu, **Japan,** 11-13 October 20, 05.

61. "Space Science Education of CSSTEAP and EDUSAT", at *APRSAF/UNESCO Space Science Education Workshop*, Hanoi, **Vietnam**, 3-4 March 2006.

R. Sekar

62. "Effect of geomagnetic storms on the development of equatorial spread F: Synthesis of a few case studies", at the *International Living With a Star (ILWS) Workshop*, Goa, **India**, February 19-24, 2006.

S. A. Haider

63. "Role of solar EUV and solar wind interaction with ionosphere of Mars", *2nd Asia Oceanic Geosciences Society (AOGS) Anuual Meeting*, Singapore, June 20-24,2005.

B. Bapat

64. "Pitfalls in Obtaining Ion Kinetic Energy Distributions from Time-of-Flight Spectra", *Topical Conference on Atomic, Molecular and Optical Physics TC2005*, Indian Association for the Cultivation of Science, Kolkata, December 13 -15, 2005.

Planetary and Geosciences

S. K. Bhattacharya

65. "Application of Stable Isotopes in Palaeoclimatology and Palaeoecolgy", in Training Workshop on *Isotope Ratio Mass Spectrometry*, NIO, **Goa**, October, 2005.

S. K. Gupta

66. "Potential of Soil-Aquifer-Treatment in Contaminant Removal and Groundwater Recharge - Gujarat Ex-

perience", at *Conference on Health and Environment*, CSE, **New Delhi**, March 24-25, 2006.

M. M. Sarin

67. "Mineral Dust and Anthropogenic Trace Element Inputs to the Tropical Indian Ocean", *Asia Oceania Geosciences Society, 2nd Annual Meeting*, **Singapore,** June 20-24, 2005.

R. Ramesh

68. "Paleomonsoon studies in the Asian region"", in the *UK-India Workshop on Regional Climate Change, variability and impacts: scientific perspectives*, held at IITM, **Pune** January 23-27, 2006.

J. S. Ray

69. "Tracing atmospheric particles through Carbon and Lead isotopes", *Workshop on Environmental Health Impacts from Exposures to Metals, World Health Organization* , **Shimla**, June 1-3 , 2005.

A. K. Singhvi

70. **Keynote talk** on "Monsoon and man in the Indian subcontinent", at the *IGBP-PAGES Open Science Meeting*, Bejing, **China,** August 9-11, 2005 .

71. **Keynote talk** on "Luminescence chronometry of land records : Applications and implications", in *Symposium on Fluvial Systems,* Indian Statsitical Institute, **Calcutta**, August 14, 2005.

72. "Luminescence dating and the paleoclimate reconstruction", *Special Symposium on the Indian Monsoon,* Indian Institute of Tropical Meteorology, **Pune**, November 28, 2005**.**

73. "Land and marine records Indian climate variability during the Holocene, present status, unresolved problems, problems and societal implications", *START meeting on Monsoon Asia Reconstruction*, Colombo, **Srilanka**, July 9 -10, 2005.

S. K. Singh

74. "Chemical erosion and CO_2 consumption in river basins of India", in *International Symposium on Quaternary Studies*, held at PRL, **Ahmedabad**, March 2, 2006.

PLANEX

J. N. Goswami

75. "India's mission to moon: Chandrayaan-1", in *International meeting on Lunar Science - The next Decade*, Bonn, **Germany**, June 5-10, 2005.

76. "Chandrayaan-1: Technological and Scientific Challenges", in *IAA Asia-Pacific Regional Conference on Advances in Planetary Exploration*, **Bangalore**, June 26-29, 2005.

77. "Planetary Exploration: An Indian Perspective", *Plenary Talk in National Space Science Symposium*, **Visakhapatnam**, February 9-12, 2006.

78. "Chandrayaan-1 Mission to Moon", in *ILWS Workshop*, **Goa**, February 19-24, 2006.

6th PLANEX Workshop on
Remote Sensing & Chandrayaan Mission
NRSA, Hyderabad
October 23 - 28, 2005

Name	No. of lectures	Topic
J.N. Goswami	2	PLANEX and Chandrayaan-1 Origin of Solar System
D.Banerjee	2	Fundamentals of Remote Sensing of Energetic Particles HEX
P.N. Shukla	2	Origin of Moon Meteorites from Moon : What they tell us
SVS Murty	2	Evolution of Inner Planets, Recent Results from Mars Future Indian Planetary Exploration : Science issues
Deepak Dhingra	2	Remote Sensing of EROS Mineral mapping of Planetary Surfaces
Neeraj Srivastava	1	Elemental mapping of Planetary Surfaces
S. A. Haider	1	Cassini Huygen Mission

Workshop on
Thirty years after Dhajala Mmeteorite Shower:
Progress in Planetary Sciences
January 29, 2006
Physical Research Laboratory, Ahmedabad

1.	N. Bhandari	Hunting for Meteorite
2.	D. Lal	Lesson Learnt from Dhajala Meteorite
3.	S. V. S. Murty	Meteorites: Poorman's Space Probes
4.	J. R. Trivedi	Fall and Recovery of Dhajala Meteorite

Workshop on
Remote Sensing and Chandrayaan-1 Data Analysis
6-7 March, 2006
Physical Research Laboratory, Ahmedabad

1.	J. N. Goswami	Chandrayaan-1 Mission: An Overview
2.	N. Bhandari	Chandrayaan-1 Mission: Science Perspectives
3.	D. Banerjee and S. Vadawale	X-ray Payloads on Chandrayaan-1
4.	Deepak Dhingra and Neeraj Srivastava	Analysis of Clementine Data: Implications to Lunar Science

Science at PRL

Detection of a Rare Infrared Light Echo in Eruptive Variable V838 Monocerotis

The outburst of the eruptive variable V838 Monocerotis (V838 Mon) in early 2002 has been extremely unusual in several aspects. Features such as, multi-peaked outbursts within few months, decreasing effective temperature and increasing size etc. make it one of the brightest objects in our Milky Way galaxy. In addition, it has displayed an expanding spectacular light echo resulting from the scattering of the outward propagating radiation of the 2002 outburst. The origin of light echo material is a subject of intense debate with two competing models attributing it to circumstellar material and alternatively to interstellar molecular clouds. We had obtained observing time on the Spitzer Space Telescope to extend our study to far-infrared wavelengths spanning the range 20 to 180 μm where the cool dust can be effectively detected. The highlight of our Spitzer observations is the detection of a striking infrared echo seen around V838 Mon. The comparison of our extended emission in 3 wavebands at 24, 70 and 160 μm with optical light echo pictures obtained by Hubble Space Telescope (HST) shows strong spatial correlation. Based on this we infer that the diffuse nebulosity seen in our Spitzer images arises from the reprocessed thermal emission from the dust heated by the radiation from the 2002 outburst of V838 Mon.

V838 Mon images were obtained with the Multiband Imaging Photometer for Spitzer (MIPS) in October 2004 and April 2005. The image at 70 μm is shown in **Fig. 1.1.** The bright source at the centre is V838 Mon and the extended nebulosity offset from the central star is clearly seen. We have compared our infrared image with the optical light echo image obtained from archival HST images of V838 Mon taken in October 2004. The contribution due to the central source is subtracted to get the extended emission and is compared with HST image convolved with MIPS resolution at 70 μm. In addition, intensity contours of 70 μm extended emission are superposed on the three colour composite HST image of V838 Mon (**Fig.1.2**). There is striking similarity between Spitzer far-infrared image and HST optical image. We further took advantage of detection of the IR light echo to estimate the mass of the dust light echo material and consequently constrain its origin. We have computed the spectral energy distribution of the extended nebulosity around V838 Mon and fit it with two modified blackbodies at ~ 25K and 63 K. Based on the detection of infrared light echo at wavelengths where the scattering efficiency of dust grains is small compared to their absorption efficiency we infer that IR light echo arises from the thermal emission from grains heated by the 2002 outburst - unlike the optical light echo that results from scattering of outward propagating radiation from the outburst. We have

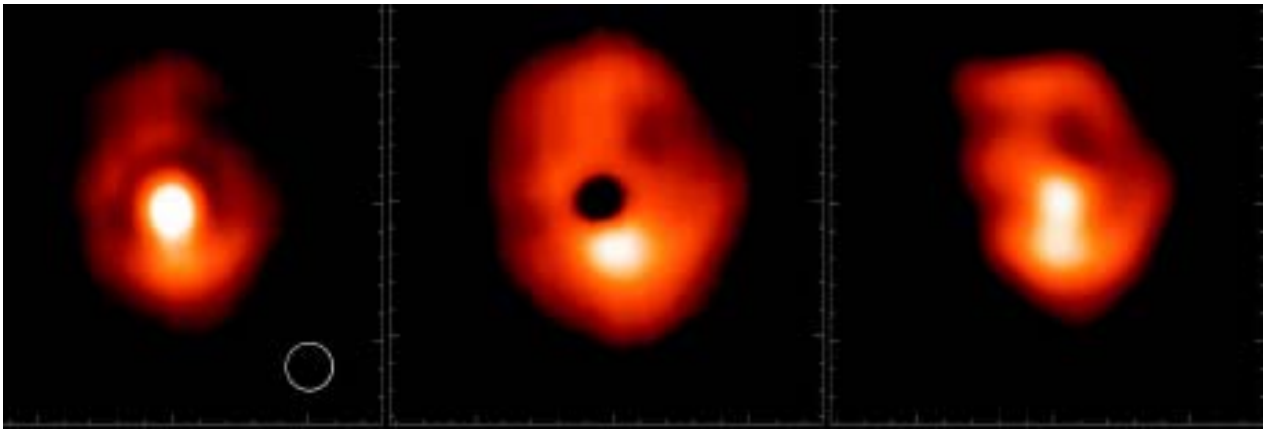


Fig. 1.1 Multiwavelength images of V838 Mon. The left and central panels show Spitzer Space Telescope images in the far-infrared (70μm), and the right panel shows Hubble Space Telescope image at optical wavelengths convolved to the spatial resolution of the Spitzer image. In the central panel the bright central star is removed to show clearly the IR light echo.

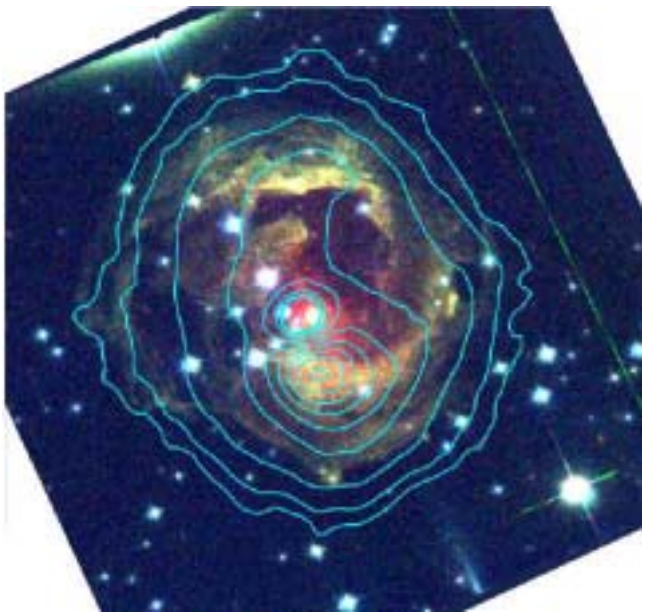


Fig. 1.2 Morphological comparison between Spitzer far-infrared and Hubble optical light echo images. The far-infrared contours are overlaid on the optical image.

next addressed whether it is circumstellar or interstellar as it is an important aspect and helps to establish the evolutionary aspects of the progenitor star like whether it has undergone previous outbursts or steady mass-loss through winds in the past. By comparing the observed flux densities by MIPS with the expected flux densities from a collection of dust grains in the size range 0.1 to 1 μm composed of silicate and amorphous carbon grains we arrive at an estimate of 0.5 to 5 $M_{\odot}$ for the dust component of the light echo. Taking a typical value of 100 for the gas-to-dust ratio, the total mass of IR echo material ranges from few tens to a few hundred solar masses considering the uncertainties in the temperature and optical properties of the dust grains and distance to V838 Mon. This observed mass of the IR light echo is unlikely to be the circumstellar remnant of previous mass loss episodes but rather interstellar material along the line of sight to V838 Mon. This work is done in collaboration with K.Y.C. Su and K.A. Misselt of Steward Observatory, University of Arizona, U.S.A.

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

Detection of a Rare Infrared Flash from the Afterglow of Gamma Ray Burst GRB 050319

Gamma ray bursts (GRB) are intense flashes of high energy photons that occur randomly in the sky. Though first discovered in 1967 it was another 30 years before they were detected at other wavelengths (X-ray, UV and Optical) and precise positions determined. It is now widely accepted that GRBs originate at cosmological distances with isotropic energy releases ranging from 10^{51} to 10^{54} ergs. Most of the energy is emitted in the photon energy range 100 KeV to 1 MeV. The visible and IR emission from GRBs result when the relativistically expanding fireball interacts with the circumburst medium giving rise to an afterglow. Most of the afterglows are faint (m_v ~ 16 to 21) and fade rapidly within a day following a power law decay. While the GRB afterglows are followed up by a variety of telescopes in the visible region distributed across the globe, the IR studies of the afterglows are still very limited.

On March 19, 2005 we detected a bright near infrared flash from the afterglow of GRB 050319. This detection took place 6.15 hours after the Gamma ray burst was reported by the Swift Satellite which monitors GRB events in real time. The observations were made with NICMOS camera on the 1.2 m Mt. Abu Infrared telescope in the NIR J band (1.25 μm). The IR flash was found to fade rapidly from J=13.12 mag to J > 15.5 mag in a very short time of only 4 minutes (**Fig.1.3**). This IR flash is only the second IR flash from a GRB ever to be reported and the first IR flash to occur several hours after the GRB. Since it was a unique event great care was taken to establish, with astrometric precision, the positional coincidence of our IR flash with the reported positions of the GRB. The interpretation of the observed late IR flash in the context of current theories of GRB afterglows is difficult. Presence of angular structure in the GRB ejection or in the circumburst material or dust echoes around the progenitor have been suggested as possibilities.

(G. Koshy, T. Chandrasekhar, N.M. Ashok D.P.K. Banerjee and J.K. Jain)

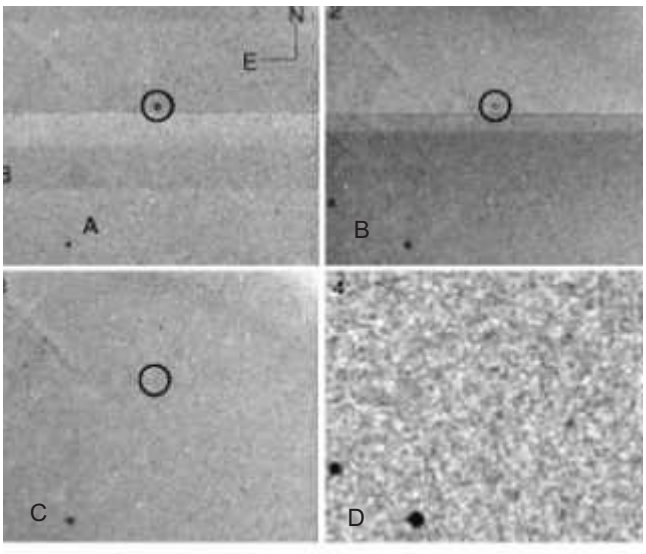


Fig. 1.3 The 1.25 μm J band images (3.2 x 4 arcmin^2) of the GRB 050319 field. The first three frames show the IR afterglow (encircled) detection (A), fading (B) and disappearance (C). The fourth (D) is comparison frame showing field stars.

High Angular Resolution Studies of Cool Carbon Stars TU Gem and SS Vir by Lunar Occultations

Carbon stars pose a challenge to the theoretical understanding of the late evolutionary stages of stars with moderate mass. Models of carbon stars have traditionally lacked sufficient observational constraints, particularly on their angular sizes and their circumstellar environment. Angular diameters permit determination of effective temperatures and also estimation of linear radii if reliable distance measurements are available. We present new accurate angular diameter measurements by lunar occultations of two cool carbon stars TU Gem and SS Vir.

These lunar occultations were successfully observed in the broad K band (2.2 μm) with the fast IR photometer at the 1.2 m telescope at Mt. Abu. For TU Gem this is the first determination of angular diameter. **Figs. 1.4** and **1.5** show the lunar occultation light curves observed and the model fit along with residuals.

Our data of angular diameter 8.37 ± 0.07 milliarcsec for SS Vir is well fitted with a single uniform disk source.

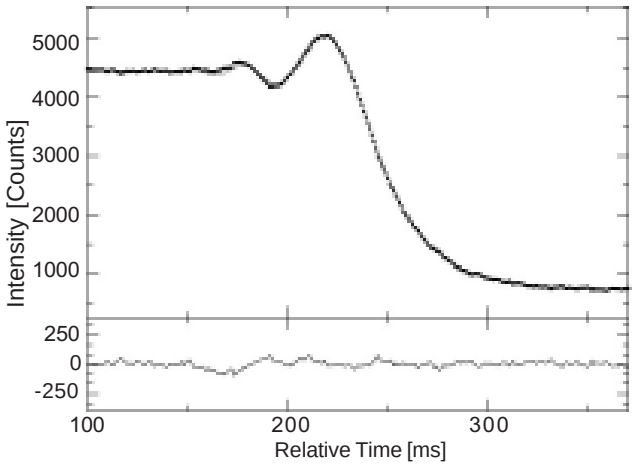


Fig. 1.4 Upper panel : SS Vir occultation data (dotted line) Model fit (solid line) Lower panel : Fit residuals enlarged by factor of 2 for clarity.

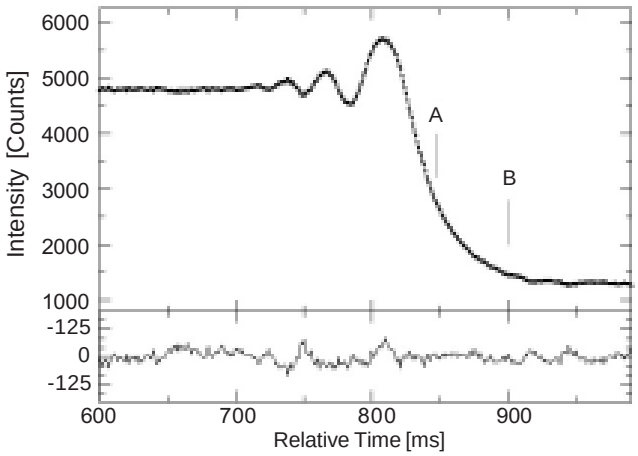


Fig. 1.5 Upper panel : TU Gem occultation data (dotted line) and Model fit (solid line) Lower panel : Fit residuals enlarged by factor of 2 for clarity. Note the higher fringe contrast with respect to light curve of SS Vir (Fig. 1.4) indicating a smaller angular size.

No circumstellar structure is detected in our observations which sets a limit of < 1% of the total K band flux on circumstellar matter in the range 15-180 (mas) or about 2-20 stellar diameters. However, circumstellar material is known to exist from other observations that addressed larger scales or different wavelength regimes. For TU Gem our observations put a limit to the flux of circumstellar

matter of about 2% in the range 15-120 mas or 3-25 stellar diameters. The derived uniform disk angular diameter is 4.62 ± 0.15 mas. The effective temperature estimated is 3162 ± 107 K which is higher than the value 2700-2800 K available in the literature. The interest in TU Gem was triggered by its earlier classification as a cool CH Giant which was also a binary system. TU Gem is listed in the Tycho 2 Double Star Catalog (TDSC 14074). The two components are separated by 380 mas. However from our observations we do not detect the binary but derive V-K=6.95 for the primary and V-K £ 4.2 for the secondary. While the primary is consistent with a cool giant star we cannot constrain the spectral type of the companion.This work is done in collaboration with A. Richichi of European Southern Observatory, Garching, Germany.

(T. Chandrasekhar)

Stellar Occultation by Asteroids

Occultations of stars by asteroids provide a direct means of measuring the length of the chord across the asteroids with good accuracy. The measurement has the advantage that it is not dependent on the brightness of the asteroid or its location in the solar system. It can also pinpoint if the asteroid has any binary structure by secondary dips in the occultation light curve. This program has resulted as an offshoot of our attempts to use sub-array fast imaging in NICMOS IR camera for lunar occultation work.

During 2005, two asteroid occultations (7 Iris, and 11 Parthenope) were successfully observed in J band of NICMOS Camera at Mt. Abu Observatory. On both occasions 20^2 x 20^2 sub-array of the NICMOS camera was used with a sampling time of about 100 milliseconds. The events were also visually monitored in a intensifier CCD. 2400 sub frames of NICMOS were recorded in 4 min 14 sec centred on the events. During the last 5 seconds the star was drifted off the sub array of data acquisition to record sky sub-frames. The duration of the occultation was 15.16 ± 0.05 sec for 7 Iris and 11.54 ± 0.06 seconds for 11 Parthenope. The derived chord lengths were 193.3 ± 0.7 km for 7 Iris and 138.7 ± 0.7 km for 11 Parthenope. One of the events (11 Parthenope) is shown in **Fig.1.6**.

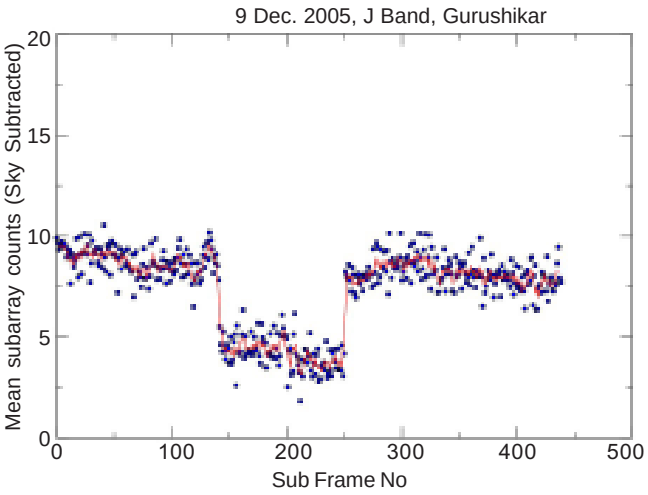


Fig. 1.6 Near-infrared J band occultation light curve of SAO 942297 by the asteroid 11 Parthenope.

(T. Chandrasekhar, Rajesh Shah, Hima Bindu and G.S. Rajpurohit)

Multi-wavelength Campaign on the Micro-Quasar SS 433

As a part of the national multi-wavelength campaign on the transient behaviour of the micro-quasar SS 433 near-infrared JHK photometry observations were made at Mt. Abu Observatory using the NICMOS camera. These observations made during the campaign held in 2002 (along with X-ray observations from RXTE satellite, optical observations from VBT, Kavalur, and radio observation from GMRT) revealed sharp variations in intensity on time scales of a few minutes in all the wavelength bands. Differential photometry in JHK' bands performed from the Mt. Abu observations clearly indicated significant intrinsic variations on short time-scales of a few minutes. These variations are expected to occur due to shock oscillations in the advective flows at the base of a jet, that is produced by the matter ejected from the accretion disc surrounding the micro-quasar SS 433. This work was done in collaboration with S.K Chakrabarti of S.N. Bose National Centre for Basic Sciences, Kolkata.

(B.G. Anandarao and S. Mondal)

Post-outburst Phase of Young Stellar Eruptive Variable V1647 Orionis

V1647 Orionis is a low mass young stellar object that had undergone an outburst process more than two years ago (January 2004) releasing a large reflection nebular matter called now as Mc Neil's nebula. We have been following this object's near-infrared photometric behaviour since 2004 February in order to understand the nature of the object. Our observations spanning nearly two years since the eruption showed clearly that the object had faded away reaching nearly its 2MASS pre-eruptive luminosities. Among theYSO of low masses, a few cases showed eruptive phenomenon that lasted typically for over 10 years (called FUors) or 2 years (called EXors). The phenomenon occurs due to increased accretion rate from the disc surrounding the proto-star. In view of the relatively short term eruptive phenomenon, we attribute this behaviour to that of EXor type. These observations formed a part of the national campaign at multi-wavelengths on this object involving PRL, IIA and TIFR.

(B.G. Anandarao and V. Venkataraman)

Temporal Evolution of Nova Sgr 2001 (V4643 Sgr) during Early Decline Phase

V4643 is an exceedingly fast nova and our observations soon after the outburst have shown that the spectra are dominated by emission lines of hydrogen and accompanied by the OI line at 1.1287 μm which show broad wings and a relatively narrow wine bottle shaped central peak. The higher order Brackett series lines (n = 10 to 14) were present in the spectra while the Brackett γ (n = 7) line was absent and appeared in the spectra taken after about 10 days indicating a varying optical depth in the nova ejecta. The OI line at 1.1287 μm, produced by the fluorescence mechanism involving excitation by Lyman β photons, mimics the broad shape of the HI lines and displays rapid changes, indicating changes in the optical depth in the nova ejecta. The line ratios of Brackett series deviate substantially from case B values again indicating optical depth effects. About 120 days after the discovery date, the K band spectrum taken from the 3.8m UKIRT telescope is dominated by the emission lines due to [SiVI] and [SiVII] at 1.963 and 2.476 μm indicating that the nova had entered the coronal phase. These coronal lines show multiple components and large expansion velocity. There is no evidence of dust emission in our observations as normally observed in case of fast novae. Our closely spaced observations soon after the nova outburst vividly bring out the fast changing spectral characteristics and the need for such closely spaced observations in other fast novae in future. This work is done in collaboration with W.P. Varricatt of Joint Astronomy Center, Hawaii, USA.

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

Study of a Typical Field in the Disk of the Milky Way

A comprehensive multi-wavelength study of a large field in the disk of the Milky Way has been carried out. The result is a 12 band catalog of stars towards a direction tangential to the spiral arms towards the inner Milky Way. We have combined data from DENIS, 2MASS, ISOGAL and the GLIMPSE Spitzer Survey to build this catalog. The locus of the red-clump as a function of distance has been determined for this field in the colour-magnitude diagrams and with additional input from the AGB isochrones distance and extinction have been estimated for a large fraction of the sources detected. Their intrinsic properties have also been studied. It is found that the extinction law used in the solar neighbourhood cannot be used directly for this field across the galactic plane and beyond distance of 2 Kpc. Number density as a function of distance has been derived and compared with existing CO spectral information. Good correspondence is found between the spectrum and the stellar number density as a function of distance. The method will be extended to cover more fields and to trace the spiral arms in the regions with very high extinction.

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

Intra-day Polarization Variations in Mrk 501

Mrk 501, a BL Lac object, is known to possess a moderate (2-3 %) degree of linear polarization in the optical region. This polarized emission is expected to be synchrotron radiation from the electrons in the inner relativistic jet and thus probes the very central region in such

sources. Observations of Mrk501 made on May 19, 2004 from the Mount Abu Infra Red Observatory using optical polarimeter revealed fast variations in the optical linear polarization with average degree of polarization increasing from about 2% to more than 4% in about 4 hours. Several dips in the total intensity are seen at the beginning of the observations. We also detected rapid linear polarization flashes sometimes reaching a rarely-seen-before high value close to 8% with only minor (< 0.02 mag) change in the source brightness. While gradual increase in the degree of polarization could be due to alignment of the magnetic field in blobs inside the relativistic jet, fast variations during the flashes are difficult to explain.

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

Optical and Near IR Monitoring of Blazars for Variability

In order to understand the huge energy generation mechanism of AGNs in general and blazars in particular, a sample of bright blazars is being monitored from Mt Abu Infrared Observatory (MIRO). We observed 3C66A, 3C279, 3C 454.3, Mrk 421, Mrk 501, BL Lac, OJ 287, 1ES 2344, PKS 0716 in near infrared (NICMOS-3) and optical (polarimeter and CCD). Out of these, Mrk 421, Mrk 501, 1ES 2344 and 3C66A are gamma-ray loud sources which emit substantial radiation in TeV energy regime. The low energy component of the spectral energy distribution (SED) of blazars is considered to be due to synchrotron emission from the relativistic electrons while the higher energy one, extending from X-ray to high energy gamma-rays is less understood. Long term multi-wavelength monitoring of the blazars for variability is the key to obtain information on the geometry of the jets and the physical processes. During January 25-30, 2006, we monitored Mrk 501, a TeV source, with polarimeter in co-ordination with TACTIC TeV observations by BARC group. While source appeared to be in low phase in polarization and optical flux, enhanced TeV emission was noticed at some epochs but mostly Mrk 501 was seen in quiet phase. The TeV source was at 13.4 mag level during 25-27 October 2005, brightened by 0.6 mag to 12.8 mag in J during December 4-10 2005 period. This work was done in collaboration with scientists from BARC.

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

R Band Observations of Blazar 3C66A with New Optical CCD

We have been monitoring AGNs in near infrared (1.25 to 2.12 μm). This is now extended to shorter wavelength upto 0.3 μm using a new back illuminated, 1296x1150 pixel, LN2 cooled EEV grade CCD, with pixel size 22 μm and active image area about 28 mm x 26 mm. During November - December 2005 we monitored several blazars including 3C66A, which showed significant variations, intra-night as well as on day to day basis. It was stable during November 18 and 19, 2005, showing only minor fluctuations. On November 20, it brightened by ~0.08 mag in about 2 hrs. With a similar timescale of two hours, it exhibited a brightness by 0.04 mag on December 19 while in 44 hrs during December 22-24, 2005, 3C66A was brighter by 0.33 mag in R Band (**Fig. 1.7**). Such time scales for source variation indicate the emission region size of the order of solar system.

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

Morphology of Decimetric Emission from Solar Flares

Decimetric emission illuminates magnetic field lines that requires energetic electrons. The morphology of the emission is of interest because it reflects the physical location of the radiating electrons and may therefore provide clues to their genesis. Type III like emissions, which drift rapidly from high to low frequencies, are expected to lie on open field lines, while continua confined to a narrower frequency range are expected to be on closed field lines. Determining the morphology of solar decimetric radio emission requires high resolution imaging observations, which can be achieved with the Giant Metrewave Radio Telescope (GMRT). At 617 MHz solar maps with GMRT are likely to be quite different from both lower and higher frequencies. This frequency is usually above the range of solar noise storms which often dominate the non-flaring Sun at, e.g., 327 MHz where the Very Large Array and the Nancay Radio Heliograph (NRH) can ob-

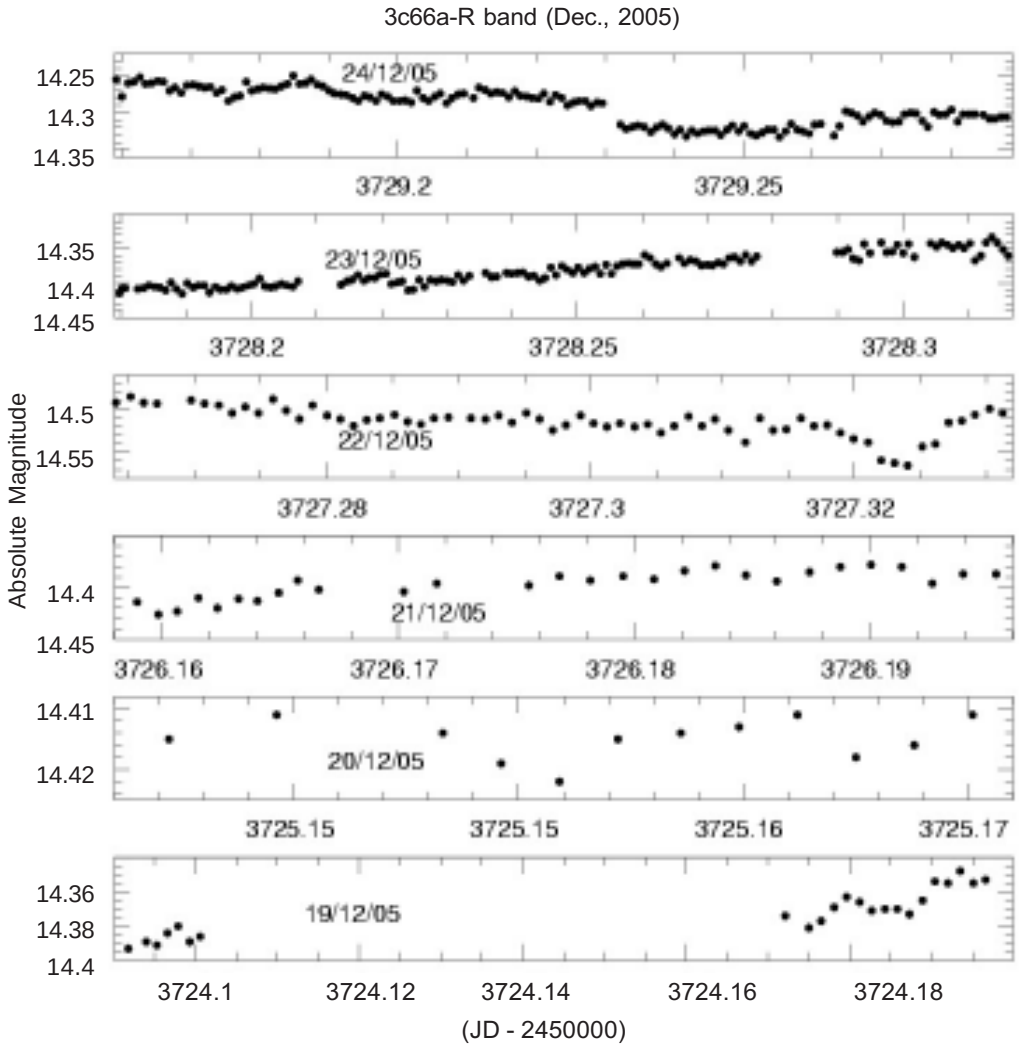


Fig. 1.7 R band light curve of 3C 66A showing infra-night variations. Error smaller than size of data points.

serve. It is also close to the plasma frequency at the level believed to separate open and closed field lines above active regions, and thus we expect to see the sources of energetic electrons which propagate from this frequency towards lower frequencies on open field lines.

Observations of a solar flare was conducted at 617 MHz with the Giant Meter Wave Radio Telescope. Images obtained were compared with microwave images of the same event from the Nobeyama Radioheliograph (NoRH) that reveal the nature of activity much lower in the corona. In this event the activity at 617 MHz precedes the main impulsive flare phase seen at other wavelengths, but it is well resolved spatially by the GMRT observations. This event has a very distinctive morphology at 617 MHz: the radio emission is clearly resolved by the 30 arc second beam into arc shaped sources seeming to lie at the top of long loops, anchored at one end in the active region in which the flare occurs, with the other end lying some 200,000 km away in a region of quiet solar atmosphere. Microwave images show fairly conventional behaviour for the flare in the active region: it consists of two compact sources overlying regions of opposite magnetic polarity in the photosphere. The decimetric emission is confined to the period leading up to the impulsive phase of the flare, and does not extend over a wide frequency range.

This fact suggests a flare mechanism in which the magnetic field at considerable height in the corona is destabilized a few minutes prior to the main energy release lower in the corona. The radio morphology also suggests that the radiating electrons are trapped near the top of magnetic loops, and therefore may have pitch angles near 90 degrees. This work was carried out in collaboration with Prof. M.R. Kundu and Dr. S. White, University of Maryland, USA; Dr. Prasad Subramanian, IUCAA, Pune; and Dr. S. Ananthakrishnan, Giant Meter Wave Radio Telescope (GMRT), Pune, India.

(P. Janardhan)

Study of Coronal Mass Ejection of November 4, 2001

The coronal mass ejection (CME) is a large outburst of magnetized plasma from solar corona. The typical mass and the speeds are 10^9 - 10^{10} tons and 250 - 1500 km/s, respectively. There have been several geo-effective events of coronal mass ejections. We investigated the CME event of November 4, 2001 from its solar origin to terrestrial effects using data of LASCO coronograph on board SoHO, GOES x-ray measurements, IPS measurements at 327 MHz, ionospheric measurements by GPS satellites, Ahmedabad Ionosonde and the Dst parameter of geomagnetic storm. This full halo CME was first observed at 1625 UT on November 4, 2001 as a bright loop over the west limb. The CME was associated with a strong X-ray flare and a prominence eruption. The material began with an initial speed of ~ 260 km/s. One day later the g-value in the interplanetary medium rose to as high as 5 indicating substantially high values of plasma density. This coupled with high speed, increased the RAM pressure on the magnetosphere. The Bz was negative which seems to have forced Dst to reach a minimum of ~ – 300 nT at 0600 UT on November 6, 2001. The analysis of Ahmedabad ionosonde data shows an unusual trend of increasing F-layer height during 0 - 3 hrs (75^0 EMT) which can be attributed to the redistribution of total electron content TEC due to electric field. This work was done in collaboration with RAC Ooty and Physics Department of SU Rajkot.

(Hari Om Vats and Som Kumar Sharma).

Light Scattering Model for Atmospheric Turbulence over Antarctic

The atmospheric turbulence is generated in several distinct atmospheric layers, especially near the Earth surface up to a height of ~ 1 - 2 km. Such turbulence creates a serious problem in the astronomical seeing. The analyses of shadow band observations of the total solar eclipse of November 23, 2003 (TSE 2003) seem to indicate that the atmospheric turbulence has Kolomogorov distribution. The diffractive-refractive scattering approach was used to develop a model of atmospheric turbulence over Antarctic based on the observations of shadow bands of TSE 2003. This approach is formulated using angular spatial frequency, Fresnel scale, autocorrelation and modified Bessel functions. The model studies indicate that the rms phase deviation introduced by the local turbulence to the dim light from the Sun, just before and immediately after the totality could be in excess of 1000 radians. This work is based on the observations of TSE at Maitri which were made in collaboration with Dr. S. P. Bagare of IIA, Bangalore and Dr S. M. Bhandari of SAC, Ahmedabad.

(Hari Om Vats)

Long Term Variability of Coronal Rotation

Experimental observations of solar rotation and its modeling is difficult as the rotation in different layers is different. Also, rotation periods inferred from different tracers in the same layer do not seem to be correlated. We have studied long term variation in coronal rotation period using radio emissions at 2800 MHz. These radio emissions originate from corona and hence can be used to estimate coronal rotation. We analyzed time series of radio data at 2800 MHz for a period from 1947 to 2005 that covers more than four solar cycles.

The auto correlation analysis was performed in block of one year and yearly mean rotation period was calculated. In most of the years strong rotational modulation is observed and yearly mean rotation period is inferred. The autocorrellogram of year 1999, in addition to regular rotational peaks, show some additional peaks. These additional peaks following regular rotational peaks repre-

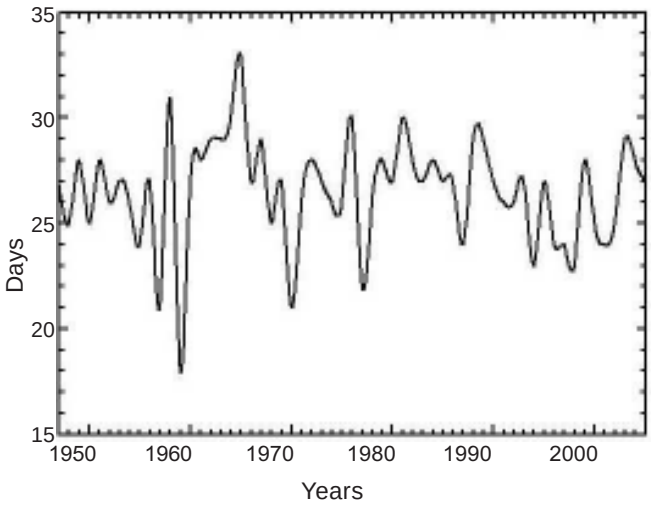


Fig. 1.8 Long term variability of coronal rotation.

sent a period larger than coronal rotational period. This phenomenon is not observed in any other year. The study of long term variation reveals cyclic behavior of solar coronal rotation (**Fig.1.8**). The value of rotation period passes through maximum and minimum. The value of synodic rotation period varies from 18 to 33 days. Generally, solar phenomena show cyclic variations which match with 11 year sunspot cycle but coronal rotation does not seem to be so. It appears that coronal rotation follows a cycle whose periodicity is approximately 25 years. This work is done in collaboration with Dr Mehul Mehta of VP Science College, Vidyanagar, Gujarat and Mr. Satish Chandra, SHD College, Sitapur, UP.

(Hari Om Vats)

Role of Solar and Interplanetary Parameters in Space Weather Prediction

The logistic regression model developed earlier was refined based on a new database of the solar and interplanetary characteristics of the major geomagnetic storms recorded during 2003-2004. The model was also used to estimate the relative importance of each solar and interplanetary variable in predicting major geomagnetic storms. In an attempt aimed at an early prediction of the occurrence of geomagnetic storms, the interplanetary variables were excluded and a new model based only on the solar variables was developed. The new model did not perform well suggesting that the solar variables responsible for geomagnetic activity at the Earth are not well-understood.

(Nandita Srivastava)

The Coronal Mass Ejection of November 18, 2003: Causes and Consequences

The super-storm of November 20, 2003 was associated with a high speed CME originating in the AR 10501 on November 18, which led to the strongest geomagnetic storm of the current solar cycle (D_{ST} index of -472 nT). A study of the photospheric magnetic field and the chromospheric images recorded at USO was made. The results revealed that the magnetic potential energy of the source active region was approximately 3.86×10^{32} ergs. A study of the interplanetary properties of the CME shows that the magnitude of a geomagnetic storm is strongly influenced by (a) the time for which the interplanetary-magnetospheric coupling parameter was active and (b) the orientation of the magnetic cloud axis.

(Nandita Srivastava and Shibu K Mathew)

Kinematics of Eruptive Quiescent Prominences Observed in He 304 Å

A geometric technique for measuring the height of prominences that are located inside the solar disk, and not exactly on the limb, was developed based on the observations taken in He 304 Å by the EIT telescope aboard SoHO. The technique was applied to five eruptive quiescent prominence images recorded in He 304 Å during January 2000-July 2003 in an attempt to identify the precursors of geo-effective CMEs that are associated with eruptive prominences. Our analyses show that prominence eruptions evolve through a pre-eruptive phase and an eruptive phase, which are characterized by lower velocities of several km s^{-1} and eruptive velocities of several tens to hundreds of km s^{-1}, respectively. The analyses also show that a prominence rises at a constant acceleration of several cm s^{-2} during the pre-eruptive phase, and not at constant velocity as reported by previous workers. This characteristic slow rise of eruptive prominences might be considered as the most reliable of all CME precursors.

(Nandita Srivastava and Vishal Joshi)

Umbral Core Brightness Variation with Solar Cycle

An increase in umbral core brightness from the analysis of 13 sunspots which cover solar cycle 20 and 21 has been reported by others. We revisit this topic by analyzing continuum images of more than 164 sunspots observed by the MDI instrument on board the SoHO spacecraft for the period between 1996 June to 2004 March, sizable part of solar cycle 23. The advantage of this data set is its homogeneity, with no seeing fluctuations. A careful stray light correction, which is validated using the Mercury transit of May 7, 2003, is carried out, before the umbral and penumbral intensities are obtained. The influence of the Zeeman splitting of the nearby NiI spectral line on the measured "continuum" intensity is also taken into account. We did not observe any significant variation in umbral core, mean umbral and mean penumbral intensities with solar cycle (**Fig. 2.1**), which is in contrast to the earlier findings. In the case of umbral core intensity, we do find a strong and clear dependence of the umbral brightness on sunspot size. The penumbral brightness also display a weak but distinct dependence. This work was done in collaboration with Martinez Valentin Pillet, Sami K. Solanki & Natalie Krivova.

(Shibu K. Mathew)

Distribution of Acoustic Power in and around a Large Sunspot

A large sunspot was observed by SVM-I on April 29, 2005 in NOAA 10756. Using vector magnetic field information we study the distribution of acoustic power

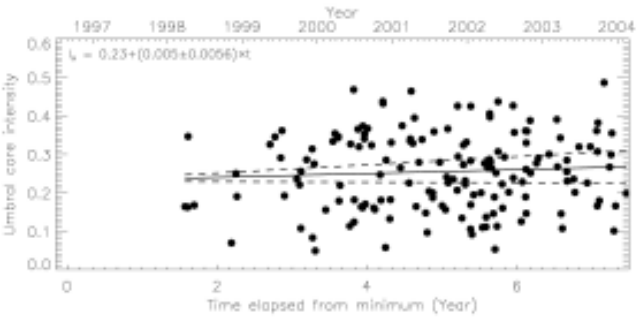


Fig. 2.1 Umbral core intensity versus solar cycle. The solid line shows the linear regression fit and the dash lines show ± 1σ deviation.

in and around this large sunspot as a function of field topology. The high ($5.5 < \omega < 7.5$ MHz) and low frequency ($0 < \omega < 5.2$ MHz) domains of the acoustic power spectrum are analyzed in relation to magnetic field strength and field inclination. It is found that the variation of acoustic power in both frequency bands as a function of sunspot radius shows a small enhancement at the umbra-penumbra boundary (**Fig. 2.2**). Further, it is found that, in the regions of strong magnetic field (B >1500 G) inside the sunspot, the ratio of acoustic power in high-frequency and low-frequency band is very sensitive to field inclination and tends to decrease with increasing field inclination. For weaker fields (B <1000 G), this ratio is such that the dependence is rather weak.

(Sanjay Gosain and P. Venkatakrishnan)

Possibility of Excitation of Low-l p-modes by Energetic Solar Transients

In order to examine the effect of the shorter lived energetic transients, we have compared the distribution function of mode power for low-l p-modes with different radial numbers using running windows of 23 days and 3 days for calculating the mean power using GONG data for the period of May 1995 - June 2005 (**Fig. 2.3**). For mode with radial number n=17, the life-time is of the order of 4 days; significantly smaller than the window of 23 days. The mode life-time decreases rapidly with n and all modes have life-times smaller than the running window size, thus for all modes the distribution function at first increases rapidly and then falls off gradually as power increases. On the other hand, the distribution obtained using smaller running window of 3 days extends over larger energy range and the peak value of the distribution is reduced. Also, the peak shifts towards lower power, and the distribution tends to exponential shape. For n=17 which now has a life-time larger than the length of running window, the peak occurs at lowest bin and the distribution falls off exponentially with power. The higher order modes have life-times which are comparable to or smaller than 3 days and show an increase with power at low end as was the case with longer running window. These changes in the shape of distribution function as T is decreased follows the expected trend as theoretically predicted, further confirming that the modes are generally stochastically excited, and the energetic transients do not have any detectable role in mode excitation at global scale. We have also compared the temporal variation of power in low-l modes with disk-integrated flare index, FI, and CME-counts using the GONG data available now for nearly the complete cycle 23. We notice that the mean level of power in p-modes is higher during the solar minimum period, which decreases during the ascending phase of the cycle and increases after the maximum phase. There are large spikes in power seen in the temporal variation, which are not well-correlated with the spikes in FI. A mild anti-correlation between the running means of flare index FI (and CME-counts) and mode power is found, which could perhaps be attributed to the magnetic fields associated with the flare producing active regions. However, the correlation coefficient between FI and CME-counts is found to be comparatively better, i.e., 0.27, which improves somewhat if data is restricted to the end of 2003. This work has been carried out in collaboration with H.M. Antia.

(A. Ambastha)

Estimation of Fried's Parameter at the Lake Site of Udaipur Solar Observatory

A Multi-application Solar Telescope (MAST) is proposed to be installed at the lake site of Udaipur Solar Observatory (USO). In order to determine the optimum size of the telescope (equipped with an Adaptive optics system), it was decided to estimate the seeing conditions prevailing at the lake site during the different months

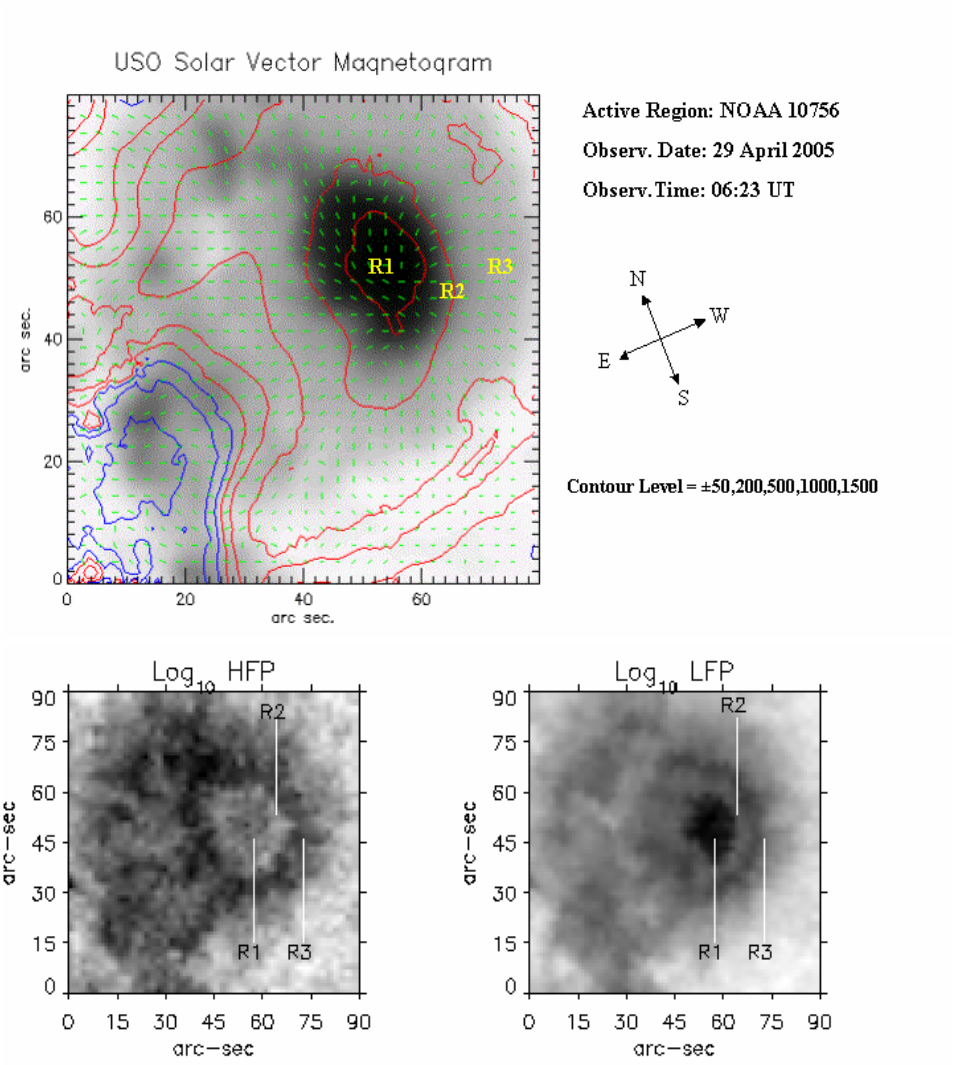


Fig. 2.2 The upper left and right panels show respectively, the continuum intensity and magnetic field strength maps of the sunspot (AR No. 10756) observed on April 29, 2005 measured using Solar Vector Magnetograph at USO. The middle left and right panels show the magnetic field inclination and azimuth, respectively. The magnetic field parameters are derived by least squares fitting of the observed Stokes profiles with theoretical Stokes profiles under the assumption of Milne-Eddington atmosphere. The lower panel shows, on left and right respectively, the acoustic power map in high frequency (5.5 $<\omega<$ 7.5 MHz) and low frequency (0 $<\omega<$ 5.2 MHz) bin. The three distinct regions labeled as R1 (central umbra) , (R2 umbra-penumbra boundary) and R3 (outer penumbra) are identified.

of the year. For this purpose, we have used short exposure (3 ms) high resolution H-alpha images (spatial scale of 0.55 arc-sec per pixel) taken in burst mode from the 15 cm refractor Spar telescope located at the lake site of USO. Spectral ratio technique has been used to estimate the Fried's parameter (r_0) at this site, which gives the quantitative measure of astronomical seeing. This study has been carried out everyday on hourly basis during USO observing hours for the period January-June, 2005. The mean 'r_0' varies between 3.0-3.5 cm for this period. The solar observations got interrupted after the onset of monsoon in the last week of June, 2005. The

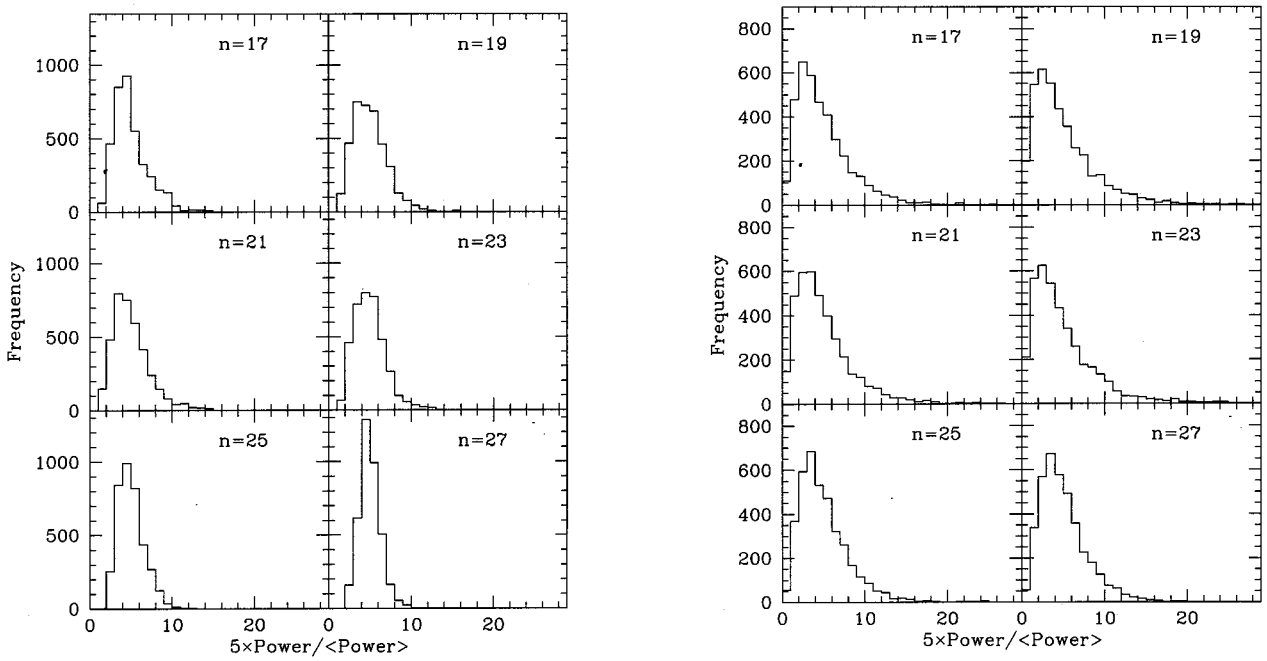


Fig. 2.3 The left panel shows the distribution function of E_T< E> for l=0, radial modes n=17, 19, 21, 23, 25, 27 using a running window of T=23 days. This function is obtained from the running mean power after normalisation by an average over the entire time span. The right panel shows the same using a shorter running window of T=3 days.

lake got completely filled after the rains and we started observation again from the last week of December 2005. The lake with water showed improvement in 'r_0' with respect to previous dry condition and mean varies between 4.0-4.5 cm for the data obtained between January-April, 2006.

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

Solar Vector Magnetograph Data Reduction and Analysis Package

In the phase-I of Solar Vector Magnetograph (SVM-I) project the optical assembly of the SVM was mounted on the German equatorial mount and housed in a rooftop observing station. The first-light observations were obtained after the integrated testing of the opto-mechanical subsystems with the control software. In order to reduce the SVM data a user friendly reduction and analysis package with Graphical User Interface was developed in IDL and Visual Basic. The package provides an integrated platform for performing series of data reduction operations. These operations include removal of dark and bias signals, as well as correcting for non-uniformity of detector gain and dust marks in the images by the process of flat-fielding. Also, it allows data processing like registration of frames, co-alignment of data-cubes and visualization of spectral profiles over the image. The package was designed and implemented indigenously using Visual Basic and IDL ActiveX components.

(Sanjay Gosain, P. Venkatakrishnan and K. Venugopalan)

Adaptive Optics System at Udaipur Solar Observatory: Phase II

Udaipur Solar Observatory is involved in the development of an Adaptive optics system for high resolution imaging. The first phase of this project i.e., development of the image stabilization system was completed in 2005. In the second phase, higher order correction is aimed. For higher order correction, the wave-front is es-

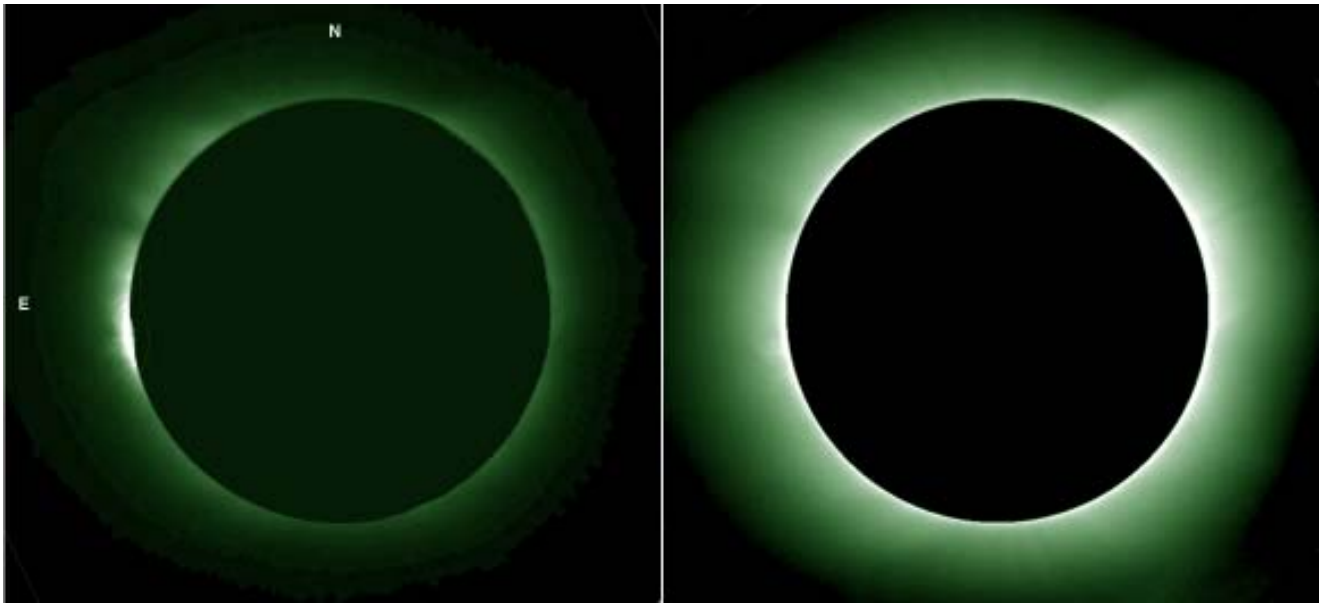


Fig. 2.4 (left) Image of the solar emission corona obtained using a narrow passband filter (FWHM 1.6 Å) centered at 5303 Å (corresponding to the green line of Fe XIV) from Manavgat-Antalya (Turkey) on March 29, 2006 at 10:55 UT. An intensely bright loop structure is seen near the E-limb which is associated with an active region located there. Solar north and east directions are as marked. (right) The same as in (left), but enhanced logarithmically to show the fainter coronal structures away from the limb.

timated locally using a lens-let array and corrected with a deformable mirror. We use a 9 by 9 hexagonal shaped lens-let array for estimation of local tilts of the distorted wavefront. We use only the central 14 lens-lets for the present set up. The code for estimating the shifts from the lens-let images is being improved for better accuracy and successfully tested with a laboratory source. The lens-let assembly is now ready to be integrated with the image stabilization system. This work is being done in collaboration with R. Sridharan of STScI, USA.

(A. Raja Bayanna, Brajesh Kumar, P. Venkatakrishnan and Shibu K. Mathew)

White Light and E-Corona during the Total Solar Eclipse of March 29, 2006 From Manavgat-Antalya, Turkey

The USO-PRL team observed the total solar eclipse on March 29, 2006 from Manavgat-Antalya, located on the center line of totality at N 36^{o} 48' 56" E 31^{o}18' 20", altitude 4 meters in Southern Turkey at the shore of the Mediterranean Sea. The observed duration of totality was 3 min 44 sec. During our TSE expedition at Manavgat, we successfully obtained digital images of the corona using filters centered at green-line 5303 Å (FWHM 1.6 Å) (**Fig. 2.4**), 5303 Å (FWHM 12 Å), H-alpha 6563 Å (FWHM 12 Å) and a neutral density filter. We used an 8-inch aperture Celestron as the light-feed and designed it to provide a F-O-V of ~ 1.3x1.3 degrees at the detector plane. The telescope, filter wheel, polaroid wheel and a thermoelectrically cooled 16-bit, 1024x1024 CCD camera were mounted on a German equatorial mount. The filter wheel was enclosed in an oven with a temperature controller to avoid the line-shift during the observation with changing ambient temperature. The system was interfaced with a PC for controlling the equipment and recording the data.

(Ashok Ambastha, Sudhir Gupta, A. Raja Bayanna, Shibu K. Mathew, Sanjay Gosain and B.L. Paneri)

SMM Astronomy

We have initiated the survey of dark, quiescent clouds using millimeter/submillimeter observations in a collaborative basis. As a first step to this, the survey of L134N dark cloud was made using CO and its isotopic lines. Analysis of these lines was further extended and column density and abundance determinations were carried out. L134N reveal complex molecular emission distributions, which are suggestive of real chemical abundance and density gradients. We are exploiting radiative transfer software to understand the molecular abundance in the excited states. We have carried out the spectral line modeling of CO lines using the 1-D code RATRAN assuming spherical symmetry of the cloud. Radiative transfer modeling of these lines demonstrate the relative sensitivity of the expected emission line characteristics to the various free parameters, which can thus be used to identify the important characteristics of the molecules in the dark clouds. Strong, high-J rotational transitions of the abundant species such as CO, HCN and HCO^+ will provide unique information on hot cores as well as on young low-mass stars. A unique feature in the 1.0 THz window is the fundamental rotational transition of para-H_2D^+. This molecule is a key player in deuterium fractionation in the interstellar medium and the 1.37 THz transition lies 65 K above the ground state (0 K) offering the best chance to detect this molecule in the ISM. We plan to carry out surveys of clouds sampling different temperature regimes to understand the deuterium chemistry.

(Hemant Dave, Satheesh Thampi, Ashish Dubey and Ravindra Pratap Singh)

SMM Technology Development

LO Development

In the continuation of development of compact SMM / FIR laser source for space applications, we have modified the theory of microwave metallic real size waveguides to the oversize dielectric waveguides with slots on top surface, for simulating the output intensity profile in the elevation plane. Based on this we have calculated the total output power for a particular line (118.8 mm line from CH_3OH) in THz region. Our calculation shows 8 -10 % increase in the THz output power in comparison to the commercially available systems. These results have also been verified by the High Frequency Structure Simulator.

(Hemant Dave and Ashish Dubey)

THz Imaging

SMM Group is developing the instrumentation for imaging and material characterization at THz frequencies. We have developed a three axes raster scanning mechanism for coherent imaging using a single pixel detector. Automation of this system is being perfected using visual basic. A two beam Mach-Zahender type interferometer is being developed for characterizing semiconductor and bio medical materials.

(Hemant Dave, A. B. Shah, Ravindra Pratap Singh, Ashish Dubey and Satheesh Thampi)

High Resolution IF 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. The design of Surface Acoustic Wave (SAW) and Reflective Array Compressor (RAC) devices for CTS has been carried out successfully. To fine tune the dispersion requirements, second iteration of the design has begun. The new design carries 200 times acoustic wavelength as launching aperture of the grooves, which is larger than the one in the previous one. 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.

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

Multi-wavelength Study of Solar Flares with Remote Brightening as a consequence of Loop Interaction in NOAA AR 10656

A recurrent solar flare activity including micro to major flares was observed in NOAA active region 10656

between August 8 - 18, 2004. A detailed analysis of four flares observed on August 12 and 14, 2004 has been carried out where the emitting structures in soft and hard X-rays, EUV, H-alpha and radio at centimeter wavelengths are compared. On August 12, 2004, discrete but continual flux emergence of positive polarity at several locations surrounding the leading sunspot of negative polarity was observed in this region. Flux emergence of negative polarity at some locations was also observed surrounding following sunspot of positive polarity. This configuration made the region very complex. The emerging flux of negative polarity was found to be moving towards the following sunspot and causing flux cancellation, which suggests interaction of the growing small loop with the pre-existing large coronal loop. Hard X-ray, radio and H-alpha emission from the flare showed bipolar structure near following sunspot site and also emission at the remote site of negative polarity (leading sunspot). In contrast, on August 14, 2004 we found emergence of flux of positive polarity surrounding the leading sunspot of negative polarity and cancellation of the flux, which caused the interaction of loops and triggered the flares. This is also supported by our radio and H-alpha observations of these flares. In both August 12 and 14, flares we observed remote source brightening in radio and H-alpha datasets. SOXS hard X-ray spectra in 10-50 keV energy band and radio emission at centimeter wavebands showed 12 and 14 August flares to be of thermal and non-thermal nature, respectively, indicating that strong flux was involved in 14 August flare. This was confirmed using MDI magnetograms that showed emerging flux of high magnetic field strength growing in area and moving towards main leading sunspot of opposite polarity. In **Fig. 3.1** we show the sequence of H-alpha filtergrams of August 14, 2004 flare observed at Beijing Astronomical Observatory, China and X-ray emission light curves as observed by SOXS mission. Non-thermal hard X-ray emission above 30 keV observed after main flare was possi-

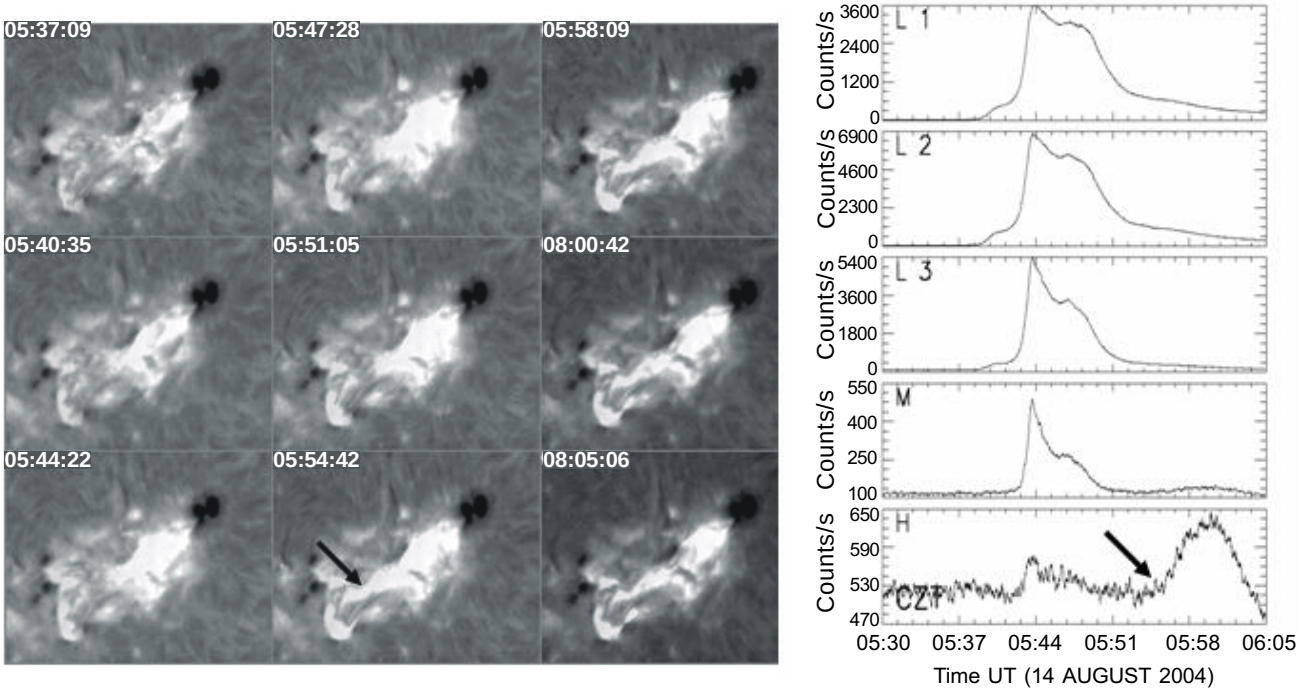


Fig. 3.1 Sequence of H-alpha fltergrams (left) of August 14, 2004 flare observed at Beijing Astronomical Observatory, China simultaneously with SOXS observations shown in right side. The main solar flare started around 05:42 UT, near leading sunspot, which emitted strong soft X-rays and weak hard X-rays indicatng loop-loop interaction as mechanism. However, a remote brightening shown by arrow may be noted that triggered a secondary flare due to strong hard X-ray emission seen around 05:54 UT.

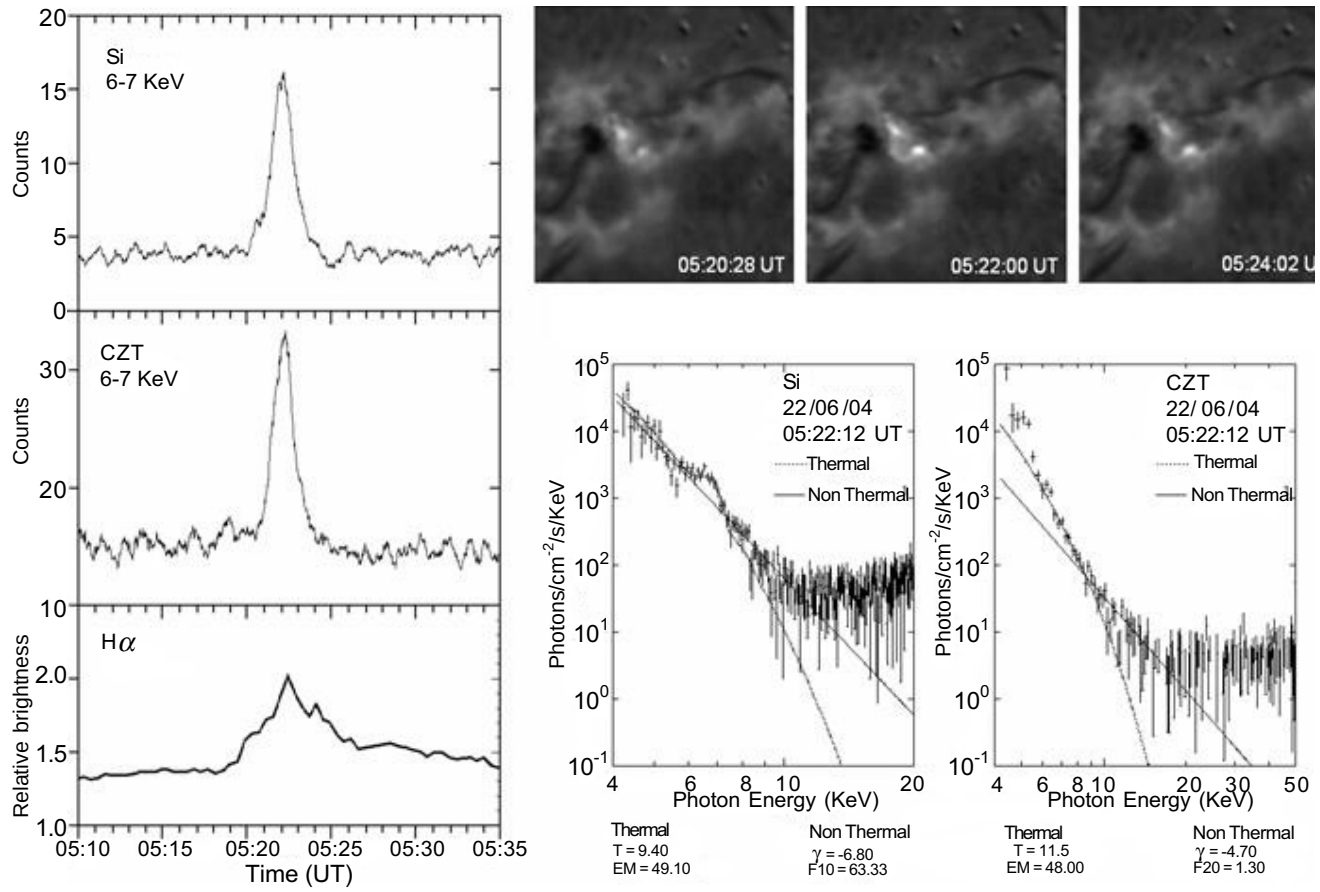


Fig. 3.2 X-ray light curves in 6 - 7 and 7 - 10 keV as seen by Si and CZT detectors of SOXS mission respectively, and light curve in Hα on 22 June 2004 microflare over the same time interval. The H-alpha filtergrams of the same microflare observed from National Astronomical Observatory of Japan (NAOJ) are also shown. It may be noted from the figure that the X-ray photon spectrum for the same microflare revealed by Si and CZT detectors show hybrid spectrum consisting of thermal plus non-thermal components.

bly due to shock induced flare seen in H-alpha also as delayed flare. Micro and sub-flares preceding major flares of August 12 and 14, and movie of MDI magnetograms also appear to suggest that active region interaction between newly emerging small loop and pre-existing main loop was the cause of perhaps all flares triggered in this region in general and those occurred on August 12 and 14, in particular. This work was done in collaboration with scientists from Beijing Astronomical Observatory, China.

(Rajmal Jain)

X-ray Emission Characteristics of Microflares Observed by SOXS Mission:

A study of 10 microflares observed in 4 - 30 keV by SOXS mission along with H-alpha observations made at National Astronomical Observatory of Japan (NAOJ), Japan during the interval between February and August 2004 is carried out. In **Fig. 3.2,** we show X-ray light curves in 6 - 7 and 7 - 10 keV as seen by Si and CZT detectors of SOXS mission, respectively, and light curve in H-alpha of June 22, 2004 microflare over the same time interval. The H-alpha filtergrams of the same microflare

observed from NAOJ are also shown. The X-ray and H-alpha light curves showed that the life time of the microflares varies between 4 to 25 min. We found that the X-ray emission in all microflares under study in the dynamic energy range of 4 - 30 keV can be fitted by thermal plus non-thermal components (**Fig. 3.2**). The thermal spectrum appeared to start from almost 4 keV, low level discriminator (LLD) of both Si and CZT detectors, and ends below 8 keV. We also observed the Fe line complex features at 6.7 keV in some microflares and attempted to fit this line by isothermal temperature assumption. The temperature of isothermal plasma of microflares varies in the range between 8 and 10 MK while emission measure between 0.5 - 2 $X10^{49}$ cm^{-3}. Non-thermal (NT) emission appeared in the energy range 7 - 15 keV with exponent $-6.8 < \gamma < -4.8$. Our study of microflares that occurred on February 25, 2004 showed that sometimes a given active region produces recurrent microflare activity of similar nature. We conclude from X-ray and simultaneous H-alpha observations that the microflares are perhaps the result of interaction of low lying loops. This work has been done in collaboration with scientists from National Astronomical Observatory of Japan, Japan.

(Rajmal Jain, Vishal Joshi and Nipa Upadhyay)

High Energy and Astroparticle Physics

Space-time Structure of New Physics with Polarized Beams at the Linear Collider

We approach the issue of the discovery of new physics at high energies associated with the proposed International Linear Collider in the presence of longitudinal as well as transverse electron and positron beam polarization. We determine the beam polarization dependence and the angular distribution of a particle of arbitrary spin in a one-particle inclusive final state produced in e^+e^- collisions through the interference of γ or Z amplitude with the amplitude from new interactions having arbitrary space-time structure. We thus extend the results of Dass and Ross proposed at the time of the discovery of neutral currents, to beyond the standard model currents. We also extend the case of e^+e^- annihilation in the s-channel to the production of bosons due to t- and u-channel processes. Our work provides an approach to model-independent determination of the space-time structure of beyond the standard model interactions. We briefly discuss applications of the framework to popular extensions of the standard model, and demonstrate that our framework is general enough to account for certain results in the minimal supersymmetric standard model. This work has been done in collaboration with B. Ananthanarayan.

(S.D. Rindani)

Polarization and Spin Correlation Effects in Third Family Resonances

We have looked at using the polarization of third generation fermions produced at the LHC in the decay of a high-mass vector resonance, to extract information on its couplings to them. We first calculate theoretically expected polarizations taking the example of the Littlest Higgs model. We have then explored the utility of a few spin sensitive variables constructed out of the decay pion variables in case of τ and results of a parton level simulation have been presented in this case. Further, in case of t final states we have explored a few variables constructed out of the decay lepton variables. We find the azimuthal angle distribution of the decay lepton, with respect to the plane defined by t and the beam-direction, to be promising. More detailed studies taking into account experimental constraints are under way. This work has been done in collaboration with G. Azuelos, B. Brelier, D. Choudhury, P.A. Delsart, R.M. Godbole, R.K. Singh and K. Wagh.

(S.D. Rindani)

Implications of Neutrinoless Double Beta Decay: SO(10) Grand Unified Theories

The successful unification of the electromagnetic interaction with the weak interaction give us hope to unify the strong and the electroweak interactions at some very high scale into one grand unified theory. The most promising grand unified theory is based on the grand unified group SO(10), which allows gauged B-L symmetry, parity conservation quark-lepton unification at high scale, and several interesting predictions for baryon and lepton number nonconservation. We proposed a SO(10) grand unified theory with smallest Higgs scalar representations which is consistent with all phenomenology. In a variant of the model we studied the possibility of providing same see-saw masses to all fermions, the charged fermions as well as the neutrinos. The question of leptogenesis is also studied in these models. This work has been done in collaboration with G. Rajasekaran and B.R. Desai.

(U. Sarkar)

Split Supersymmetry and Extra Dimensions

From some theoretical considerations it is believed that nature possess a symmetry between the fermions and bosons, which is called supersymmetry. However, we have not seen any evidence of supersymmetry in any experiments. This motivate people to think that may be most of the supersymmetric partners are too heavy to be observed in the near future, which is called split supersymmetry. We studied models with singular extra dimensions, in which supersymmetry is broken at the boundaries in the singular localized space, which provide us in four dimensions a split supersymmetric spectrum. The standard model fermions are localized in the standard model brane, where supersymmetry is broken by the nonvanishing of the F-term of a superfield. All scalar superpartners acquire mass at this stage. The

standard model gauginos and higgsinos remain light, since their masses are protected by R-symmetry and induced only by loop contributions and contact interaction in our brane.

(U. Sarkar)

Temperature of the Inflaton and Duration of Inflation from WMAP Data

If the initial state of the inflaton field is taken to have a thermal distribution instead of the conventional zero particle vacuum state then the curvature power spectrum gets modified by a temperature dependent factor such that the fluctuation spectrum of the microwave background radiation is enhanced at larger angles. We compare this modified cosmic microwave background spectrum with Wilkinson Microwave Anisotropy Probe data to obtain an upper bound on the temperature of the inflaton at the time our current horizon crossed the horizon during inflation. We further conclude that there must be additional e-foldings of inflation beyond what is needed to solve the horizon problem.

(K. Bhattacharya, S. Mohanty and R. Rangarajan)

Constraints on Flavor-dependent Long Range Forces from Solar Neutrinos and KamLAND

The existence of new flavour violating long range (LR) interactions coupling to the differences of leptonic charges is a theoretically allowed possibility within the standard model. We assume existence of such interactions and study their impact on the solar neutrino oscillations in the context of the tree generation mixing. It is found that the LR potential can dominate over the standard charged current contribution in spite of strong constraints on couplings, α , of the LR force coming from the atmospheric neutrino data and laboratory search for the new forces. We do a global analysis of these data and obtain independent constraints on α namely $\alpha_{e\mu} < 2.6 \times 10^{-52}$ in case of the $L_e - L_\mu$ gauge interactions. The impact of the LR force on the supernova neutrino oscillations is studied and it is argued that they can provide stronger constraints on a. This work is done in collaboration with Abhijit Bandyopadhyay and Amol Dighe from TIFR)

(A. S. Joshipura)

Universal 2-3 Symmetry

Possible maximal mixing seen in the oscillations of the atmospheric neutrinos has led to postulate of a special leptonic symmetry which interchanges μ and τ degrees of freedom.We argue that such symmetry need not be special to the leptonic world and a generalized approximate 2 - 3 symmetry can be used to understand small mixing angles in the quark sector. The quark mass matrices are nearly invariant under this symmetry broken only at few percent level. In contrast, one needs quite large breaking of the 2- 3 symmetry in the leptonic sector to account for the observed mixing pattern. We present this scenario,develop a specific scheme for the 2-3 symmetry breaking and elaborate on its consequences.

(A. S. Joshipura)

LOFF Condensate in Noncommutative Field Theories

The effect of noncommutative interactions on the pairing mechanism between fermions is analyzed. We use the variational technique to analyze the ground state of the noncommutative four-Fermi interaction. Due to the noncommutative nature of the interaction the model supports fermion pairs with a total non-zero net momentum. This effect is similar to the Larkin-Ovchinnikov-Fulde-Furrel (LOFF)type of pairing that is encountered when there are two-species of fermions available at finite density. Such LOFF type of pairing is driven by the scale associated with the noncommutative theory.

(P.K. Panigrahi, T. Sreecharan. and H. Mishra)

Fermion Pairing in Cold Atoms

The phase diagram of non relativistic fermionic system with imbalanced population numbers with a fermi interaction is investigated using a variational approach. Depending upon the interaction strength the system can be in normal state, in fully gapped BCS state, gapless breached paring state or in a state with a finite momentum condensate. This is particularly of relevance to experiments on cold fermionic atoms. This work is done in collaboration with A. Mishra.

(H. Mishra)

Color Superconductivity with Magnetic Field

We study color superconductivity in presence of a magnetic field which could be relevant for physics of ultra compact astro-physical objects like neutron stars. Two flavor color superconductivity is studied with a variational ansatz statee having pairing between quarks of different flavor, spin and color in the lowest Landau level. The Gap equation is derived in presence of external magnetic field. Abelian magnetic field seems to enhance the color superconducting gap. This work has been done in collaboration with A. Mishra.

(H. Mishra)

Coherence of Fluctuations of Inflaton Field

According to inflationary scenario of cosmology, fluctuations in the inflaton field can give rise to density perturbations and thereby produce inhomogeneities in the universe. These fluctuations are considered to be quantum mechanical in nature to begin with. However, later on these fluctuations may become classical since the observed inhomogeneities in the cosmic microwave background appear to be classical. Therefore, it is important to understand how and when the transition from quantum to classical would appear. We apply ideas of decoherence theory to study this transition of inflaton field.

(J. Bhatt)

Nonlinear Dynamics and Complex Systems

Synchronization of Dynamical Systems on Networks

We study self-organized and driven synchronization in some simple coupled map networks, namely globally coupled networks and complete bipartite networks, using both linear stability analysis and Lyapunov function approach and determine stability conditions for synchronization. The phase diagrams for the networks studied here have features very similar to the different kinds of structurally similar networks. Lyapunov function approach shows that when any two nodes are in driven synchronization, all the coupling terms in the difference between the variables of these two nodes cancel out whereas when they are in self-organized synchronization, the direct coupling term between the two nodes adds an extra term while the other couplings cancel out. We also discuss the conditions for the occurrence of a floating node and suggest that the fluctuations of the conditional Lyapunov exponent about zero can be a criterion for its occurrence. This work has been done in collaboration with C.K. Hu.

(S. Jalan and R. E. Amritkar)

Synchronization in Time-varying Networks

We consider synchronization properties of coupled dynamics on time-varying networks and the corresponding time-average network. We find that if the different Laplacians corresponding to the time-varying networks commute with each other then the stability of the synchronized state for both the time-varying and the time-average topologies are approximately the same. On the other hand for non-commuting Laplacians the stability of the synchronized state for the time-varying topology is in general better than the time-average topology. This work has been done in collaboration with C.K. Hu.

(R. E. Amritkar)

Spectral Fluctuations and 1/f Noise in the Order-Chaos Transition Regime

Level fluctuations in a quantum system have been used to characterize quantum chaos using random matrix models. Recently time series methods were used to relate the level fluctuations to the classical dynamics in the regular and chaotic limit. In this, we show that the spectrum of the system undergoing order to chaos transition displays a characteristic f- noise and is correlated with the classical chaos in the system. We demonstrate this using a smooth potential and a time-dependent system modeled by Gaussian and circular ensembles, respectively, of random matrix theory. We show the effect of short periodic orbits on these fluctuation measures.

(M. S. Santhanam and J. N. Bandyopadhyay)

Atomic and Nuclear Physics

Deuteron Transfer Intensities between N=Z Nuclei: IBM-ST Results

In the near future with new generation of radioactive ion beam facilities, deuteron transfer experiments between heavy (A~60-100) N=Z nuclei are possible and they will give important information about neutron-proton pairing in nuclei. Prompted by this, we have derived results for deuteron transfer intensities by considering the $O(36) \supset O(6) \oplus O(30)$ symmetry scheme, developed by PRL scientists, of spin-isospin invariant (sd)-interacting boson model sdIBM-ST. Using a mixing hamiltonian in this model, ground states are determined (they contain on the average ~20-25% d bosons) and ground to ground deuteron transfer intensities (for L = 0 transfers) are calculated between even-even and odd-odd N=Z nuclei for isospin T = 0 and T = 1 tansfers. The results are given in **Fig. 1**.

(V.K.B. Kota)

Deformed Shell Model for T = 1/2 and T = 3/2 Bands in ^{51} Mn, ^{53}Fe and ^{55}Co

Deformed configuration mixing shell model based on Hartree-Fock states with three particle isospin projection (called DSMT model) is applied to study structure of the collective bands in N = Z+1 nuclei ^{51} Mn, ^{53}Fe and ^{55}Co. The calculations are performed using the KB3 and GXPF1 effective interactions and by including very large number of deformed configurations (127, 73 and 192 for ^{51} Mn, ^{53}Fe and ^{55}Co respectively). The configuration space employed in the present calculations is largest todate in DSMT studies but still very small compared to spherical shell model. The observed T = 1/2 bands in these nuclei are reproduced reasonably well. We have also predicted many T = 3/2 levels. The experimental mixing ratios in ^{51} Mn agree reasonably well with experiment. This work is a part of our spectroscopic studies of heavy N~Z nuclei using DSMT model and group theoretical models. This work has been done in collaboration with S. Mishra and R. Sahu.

(V.K.B. Kota)

Robustness of Regularities for Energy Centroids in the Presence of Random Interactions

Continuing our earlier work, we have studied energy centroids such as those with fixed spin and isospin, those with fixed irreducible representations for bosons and fermions, in the presence of random two-body and three-body interactions. Used here are group symmetries of nuclear shell model

$$[U(2N) \supset SO(3) \otimes SU(2),\ U(2j+1) \supset SO(3),$$
$$U(N) \supset U(N/2) \otimes SU(2),\ U(N) \supset U(N/4) \otimes$$
$$\{SU(4) \supset SU(2) \otimes SU(2)\}]$$

and interacting boson model

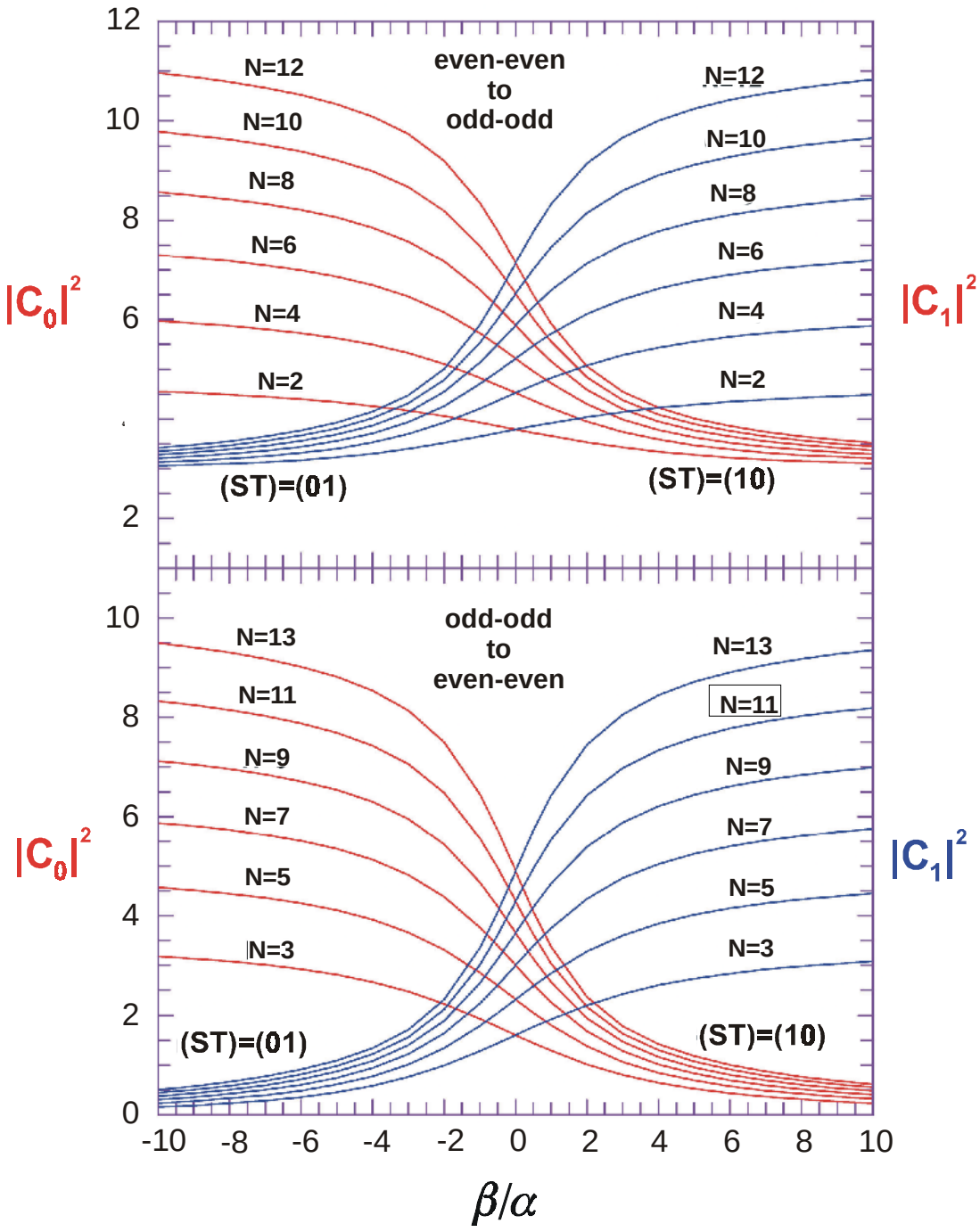
$$[U(2l+1) \supset SO(3),\ U(16) \supset \{U(6) \supset SU(3)\}$$
$$\oplus \{U(10) \supset SU(3)\}]$$

Our results confirmed that regularities of energy centroids of fixed spin states reported in our earlier works are very robust in these more complicated cases. We suggest that these behaviors might be intrinsic features of quantum many-body systems interacting by random forces. Work on regularities in spectral variances is under progress. This work has been done in collaboration with Y.M. Zhao, A. Arima, N. Yoshida, K. Ogawa and N. Yoshinaga.

(V.K.B. Kota)

Bivariate t-distribution for Transition Matrix Elements in Breit-Wigner to Gaussian Domains of Interacting Particle Systems

Interacting many-particle systems with a mean-field one body part plus a chaos generating random two-body interaction having strength "λ", exhibit Poisson to GOE and Breit-Wigner (BW) to Gaussian transitions in level fluctuations and strength functions with transition points marked by $\lambda = \lambda_c$ and $\lambda = \lambda_F$ respectively; $\lambda_F >> \lambda_c$. For these systems theory for matrix elements of one-body transition operators is available, as valid in the Gaussian domain, with $\lambda > \lambda_F$, in terms of orbitals occupation numbers, level densities and an integral involving



The T=0 (red curves) and T=1 (blue curves) deuteron transfer intensities $\left|C_T\right|^2$ *between the ground states of N = Z nuclei, in the* $O(36) \supset O(6) \oplus O(30)$ *scheme of IBM - ST, as a function of the mixing parameter* β / α. *The N values shown are boson numbers for the initial N = Z nucleus. For* $\beta / \alpha = 0$, $\left|C_T\right|^2_{ee-oo} = (N + 6)\,(N+34) / [4(N + 17)]$ *and* $\left|C_T\right|^2_{ee-oo} = (N + 1)\,(N+29) / [4(N + 17)]$. *From binding energy analysis, it is expected that* $\beta / \alpha \sim 5$.

a bivariate Gaussian in the initial and final energies. This year we have shown that, using bivariate t-distribution, the theory extends below from the Gaussian regime to the BW regime up to $\lambda = \lambda_c$. This is well tested in numerical calculations for six spinless fermions in twelve single particle states. The theory with bivariate t-distribution is being applied to calculate β - decay rates for r and rp-process nucleosynthesis. This work has been done in collaboration with N.D. Chavda and R. Sahu.

(V.K.B. Kota)

An Accurate Quantum Expression for Radiative Transition between Stark Levels of Nearby Rydberg States

We have obtained an exact new expression of the x-component of the dipole matrix element between Stark states of a hydrogen atom in terms of the Jacobi polynomials by transforming the hypergeometric functions appearing in the standard quantum formula. We have shown that the new quantum formula readily yields to analytical study as well as to numerical computation for such large values of the parabolic quantum numbers for which difficulties had earlier been encountered. We have also given an approximate but simple quantum formula of the dipole matrix element in terms of the ordinary Bessel functions and have demonstrated its remarkable accuracy for transitions ranging from that between Stark levels of low-lying states to that between Stark levels of nearby Rydberg states. The formula enables numerical computation to be performed over an extended range of large parabolic quantum numbers that had earlier defied evaluation. The expressions in essence solve the problem of determination of analytic behaviour and numerical computation of the dipole matrix element for transitions between stark levels of nearby Rydberg states. We have also derived for the first time, without appealing to any classical or semiclassical argument, the formula of the correspondence principle method from the quantum expression that clarifies the conditions of the latter's applicability. This work has been done in collaboration with Neerja and K. Basuchoudhury.

(D. P. Dewangan)

A New Quantum Mechanical Expression of the Form Factor for Transition between Rydberg Circular States of Large Quantum Numbers

Some years ago, we derived a compact quantum mechanical expression of the form factor for transition between arbitrary circular states containing a single terminating hypergeometric function and gave an asymptotic expression for transition between high circular states in terms of cosine functions. This asymptotic expression is found to give results deviating significantly from exact numerical results for moderate values of the principal quantum numbers. Using a new approximation to the terminating hypergeometric function of large arguments that we have recently obtained, we have derived a new expression in terms of the ordinary Bessel function. The new expression is accurate even for transitions connecting low values of the principle quantum numbers.

(D.P. Dewangan)

Plasma Physics

X-ray Emissions from Young Stellar Object

The recent observations by X-ray observatories in space have established the presence of strong X-ray emissions as one of the characteristics of young stellar objects. These are studied extensively, but the physical processes that lead to X-ray emissions from such stars are not fully understood. We have suggested a simple model of interaction of the magnetic field of the star with the accretation disc containing neutrals and dust particles which essentially generates current along the magnetic field. This current is found strong enough to excite kinetic Alfvein wave through plasma instability processes. These waves then accelerate particles capable of producing X-rays from such stars.

(A.C. Das)

Observation of Matter Wave Interference on the Macro-scale for Charged Particles in a Magnetic Field and the Manifestation of Landau Levels

Matter wave interference effects in the macrodomain for charged particles in a magnetic field are reported for different scatterer positions between the

electron gun and collector plate. The results obtained serve to validate and establish the important premiss of the formalism that it is the scattering, ({inter alia} off the grid wires in this case) which generates the transition amplitude waves resulting in the novel quantum effects observed on the macro-scale associated with the transition amplitude wave. The variation of the position of origin of the grid-generated transition amplitude wave then leads to the variation of interference characteristics accordingly in the plate and grid currents. A Fourier decomposition of the interference peaks reveal also the presence of harmonics which are a manifestation of the Landau level structure. A rich class of quantum phenomena are thus discovered in the simple dynamical system of charged particles in a magnetic field in the ostensibly classical domain of operation, with the transition amplitude wave generated as a consequence of scattering being the new element of quantum description on the macro-scale.

(R. K. Varma and S. B. Banerjee)

Quantum Manifestation of Systems on the Macro-scale - the Concept of Transition State and Transition Amplitude Wave

Quantum effects which have usually been associated with micro-scale phenomena can also arise on the macro-scale in situations other than the well known macro-quantum phenomena of superconductivity and superfluidity. Such situations have been shown here to arise in processes involving inelastic scattering with bound or partially bound systems (bound not in all degrees of freedom), the macro-quantum behaviour being associated with the state of the total system in transition in the process of scattering. Such a state is designated as a *transition-state*. It is pointed out that we have already observed such manifestations for a particular system, the charged particles in a magnetic field where interference effects involving macro-scale matter waves along the magnetic field have been reported

(R. K. Varma)

Quantitative Measures of Entanglement in Pair-coherent States

The pair-coherent states for a two-mode radiation field are known to belong to a family of states with non-Gaussian wave function. The nature of quantum entanglement between the two modes and some features of non-classicality are studied for such states. The existing criteria for inseparability are examined in the context of pair-coherent states.

(G. S. Agarwal and A. Biswas)

Quantum Random Walk of the Field in an Externally Driven Cavity

Using a resonant interaction between atoms and the field in a high-quality cavity, we show how to realize quantum random walks as proposed by others. The atoms are driven strongly by a classical field. Under conditions of strong driving we could realize an effective interaction of the form $iS^x(a\text{-}a^\dagger)$ in terms of the spin operator associated with the two-level atom and the field operators. This effective interaction generates displacement in the field's wave function depending on the state of the two-level atom. Measurements of the state of the two-level atom would then generate an effective state of the field. Using a homodyne technique, the state of the quantum random walker can be monitored.

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

Quantum Correlations between a Pair of Raman Photons

The quantum correlation between a pair of Stokes and anti-Stokes photons, involving a Raman emission process is calculated. All realistic radiative and nonradiative decays are included in the calculation and the photon correlation between the pair for arbitrarily strong excitation fields and detunings are calculated. The correlation function shows photon antibunching, and a damped sinusoidal behavior with respect to the time delay between the measurement of the two photons. The current system can also produce four photon entanglement. This work is done in collaboration with A. K. Patnaik, C. H. R. Ooi and M. O. Scully.

(G. S. Agarwal)

Entangling Mesoscopic Quantum Systems

We propose two schemes to establish entanglement between two mesoscopic quantum systems through a third mesoscopic quantum system. The first scheme entangles two nano-mechanical oscillators in a non-Gaussian entangled state through a Cooper-pair box (CPB). Entanglement detection of the nano-mechanical oscillators is equivalent to a teleportation experiment in a mesoscopic setting. The second scheme can entangle two CPB qubits through a nano-mechanical oscillator in the presence of arbitrarily strong decoherence.

(S. Bose and G.S. Agarwal)

Experimental Studies of Spontaneous Emission from Dopants in an Absorbing Dielectric

We report measurements of the modification of spontaneous emission rates of Eu^{3+} ions in the visible region owing to an absorbing medium. Precise levels of the absorption coefficient are introduced by codoping with different amounts of Nd^{3+}. We use a binary glass system $PbO\text{-}B_2O_3$ as the host, the compositional variation of which leads to a change in the real part of the refractive index. Measured lifetimes are found to follow the real cavity model, and the data are analyzed by the model proposed by others. We give estimates of the parameter that is related to the radius of the cavity around Eu^{3+}. This work is done in collaboration with G. M. Kumar and D. N. Rao.

(G. S. Agarwal)

Generation of Werner States

We show deterministic generation of Werner states as a steady state of the collective decay dynamics of a pair of neutral atoms coupled to a leaky cavity and strong coherent drive. We also show how the scheme can be extended to generate a 2N-particle analogue of the bipartite Werner states. This work is done in collaboration with K.T. Kapale.

(G S. Agarwal)

Cavity-mediated Long-range Interaction for Fast Multiqubit Quantum Logic Operations

Interactions among qubits are essential for performing two-qubit quantum logic operations. However, nature gives us only nearest neighbor interactions in simple and controllable settings. Here we propose a strategy to induce interactions among two atomic entities that are not necessarily neighbors of each other through their common coupling with a cavity field. This facilitates fast multiqubit quantum logic operations through a set of two-qubit operations. Using its explicit position dependence, this interaction can be employed for simulation of quantum spin systems. The ideas presented here are applicable to various quantum-information proposals for atom-based qubits such as trapped ions, atoms trapped in optical cavities, and optical lattices. This work is done in collaboration with K.T. Kapale and M.O. Scully.

(G.S. Agarwal)

Multiparticle Entanglement using Ground-state Coherences

We show how ground-state coherences and dispersive interactions of single photons with a collective system produce a variety of multiparticle entangled states and mesoscopic superpositions. Further single photons act as a carrier of information and can entangle macroscopic systems and can produce large phase shifts. Our work produces states as considered by Schrödinger in the cat-paradox, though in our case the cat is replaced by the collective atomic system. This work is done in collaboration with P. Lougovski and H. Walther.

(G. S. Agarwal)

Electromagnetically Induced Magneto-chiral Anisotropy in a Resonant Medium

Chirality has been extensively studied for well over a century, and its potential applications range from optics to chemistry, medicine and biology. Ingenious experiments have been designed to measure this naturally small effect. We discuss the possibility of producing a medium having a large chiral effect by using the ideas of coherent control. The coherent fields that resonant with appropriate transitions in atomic or molecular systems, can be used to manipulate the optical properties of a medium. We demonstrate experimentally very large magneto-chiral anisotropy by using electromagnetic fields in atomic Rb vapors. This work is done in collaboration with V. A. Sautenkov, Y. V. Rostovtsev, H. Chen, P. Hsu and M. O. Scully.

(G. S. Agarwal)

Class of Solitary Wave Solutions of the One-dimensional Gross-Pitaevskii Equation

We present a large family of exact solitary wave solutions of the one dimensional Gross-Pitaevskii equation, with time-varying scattering length and gain or loss, in both expulsive and regular parabolic confinement regimes. The consistency condition governing the soliton profiles is shown to map onto a linear Schrödinger eigenvalue problem, thereby enabling one to find analytically the effect of a wide variety of temporal variations in the control parameters, which are experimentally realizable. Corresponding to each solvable quantum mechanical system, one can identify a soliton configuration. These include soliton trains in close analogy to experimental observations by others, spatio-temporal dynamics, solitons undergoing rapid amplification, collapse and revival of condensates **(Fig. 5.1)** and analytical expression of two-soliton bound states.

(R. Atre, P.K. Panigrahi and G.S. Agarwal)

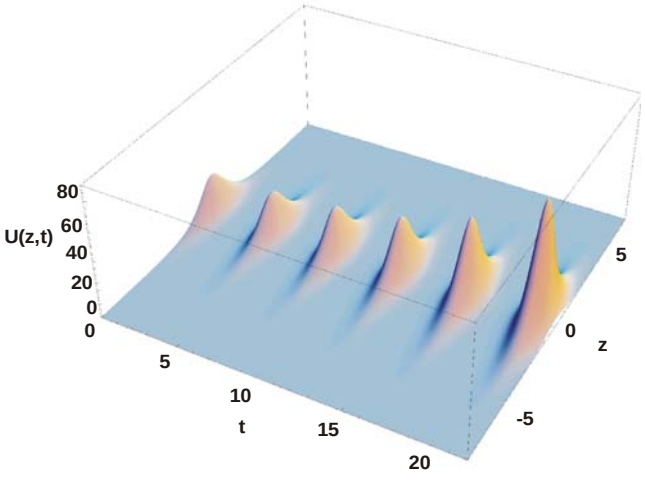


Fig. 5.1 Collapse, revival and amplification of atomic condensate through periodic exchange of atoms with the background.

Parametric Control of Solitary Wave Dynamics

We demonstrate the control of solitary wave dynamics of the modified Korteweg-de Vries (MKdV) equation through the temporal variations of the distributed coefficients. This is explicated through exact cnoidal wave and localized soliton solutions of the MKdV equation with variable coefficients. The solitons can be accelerated and their propagation can be manipulated by suitable variations of the above parameters. In sharp contrast with the nonlinear Schrödinger equation, the soliton amplitude and widths are time independent. This work is done in collaboration with K. Pradhan.

(P.K. Panigrahi)

On Exact Solitary Wave Solution of the Nonlinear Schrödinger Equation with a Source

We use a fractional transformation to connect the travelling wave solutions of the nonlinear Schrödinger equation (NLSE), phase locked with a source, to the elliptic equations satisfying, $f'' \pm af \pm \lambda f^3 = 0$. The solutions are necessarily of rational form, containing both trigonometric and hyperbolic types as special cases. Bright and dark solitons, as well as singular solitons, are obtained in a suitable range of parameter values. This work is done in collaboration with T. S. Raju and C. N. Kumar.

(P. K. Panigrahi)

Self-similar Propagation of Chirped Self-similar Waves in Asymmetric Twin-core Fibres with Nonlinear Gain

Ultrashort pulse propagation in asymmetric twin-core fibre amplifiers is studied with the aid of self-similarity analysis of the nonlinear Schrödinger-type equation interacting with a source, variable dispersion, variable Kerr nonlinearity, variable gain or loss, and nonlinear gain. Exact chirped pulses that can propagate self-similarly subject to simple scaling rules of this model have been found. It is reported that the pulse position of these chirped pulses can be precisely piloted by appropriately tailoring the dispersion profile. This fact is profitably exploited to achieve optimal pulse compression of these chirped self-similar solutions.This work is done in collaboration with T. S. Raju and K. Porsezian.

(P. K. Panigrahi)

Quantum Hamilton-Jacobi Approach to Bound and Periodic Potentials

We analyze the Scarf potential, which exhibits both discrete energy bound states and energy bands, through the quantum Hamilton-Jacobi approach. The singularity structure and the boundary conditions in the above approach, naturally isolate the bound and periodic states, once the problem is mapped to the zero energy sector of another quasi-exactly solvable quantum problem. The energy eigenvalues are obtained without having to solve for the corresponding eigenfunctions explicitly. We also demonstrate how to find the eigenfunctions through this method.

We have also applied the quantum Hamilton-Jacobi formalism, naturally defined in the complex domain, to complex Hamiltonians, characterized by discrete parity and time reversal (PT) symmetries and obtain their eigenvalues and eigenfunctions. Examples of both quasi-exactly and exactly solvable potentials are analyzed and the subtle differences, in the singularity structures of their quantum momentum functions, are pointed out. The role of the PT symmetry in the complex domain is also illustrated.

Various quasi-exact solvability conditions, involving the parameters of the periodic associated Lamé potential, are shown to emerge naturally in the quantum Hamilton-Jacobi (QHJ) approach. We study the singularity structure of the quantum momentum function, which yields the band-edge eigenvalues and eigenfunctions and compare it with the solvable and quasi-exactly solvable non-periodic potentials, as well as the periodic ones. This work is done in collaboration with S. Sree Ranjani and A. K. Kapoor.

(P. K. Panigrahi)

Wavelet-based Characterization of Spectral Fluctuations in Normal, Benign and Cancerous Human Breast Tissues

Fluorescence intensity fluctuations in the visible wavelength regime in normal, benign, and cancerous

human breast tissue samples are studied through wavelet transform. The analyses have been carried out in unpolarized, parallel and perpendicularly polarized channels, for optimal tissue characterization. It has been observed that polarized fluorescence data, particularly the perpendicular components, differentiate various tissue types quite well. Wavelet transform, because of its ability for multiresolution analysis, provides the ideal tool to separate and characterize fluctuations in the fluorescence spectra at different scales. We quantify these differences and find that the fluctuation in the perpendicular channel of the cancerous tissues are more randomized as compared to their normal counterparts. Furthermore, for cancerous tissues, the same is very well described by the normal distribution, which is not the case for normal and benign samples. It has also been observed that, up to a certain point, fluctuations at larger scales are more sensitive to tissue types. The differences in the average, low-pass wavelet coefficients of normal, cancerous, pericanalicular, and intracanalicular benign tissues are also pointed out. This work is done in collaboration with S. Gupta, M.S. Nair, A. Pradhan, N.C. Biswal, N. Agarwal and A. Agarwal.

(P. K. Panigrahi)

Coherent states of the Pöschl-Teller Potential

A recently developed algebraic approach for constructing coherent states for solvable potentials is used to obtain the displacement operator coherent state of the Pöschl-Teller potential. We establish the connection between this and the annihilation operator coherent state and compare their properties. We study the details of the revival structure (**Fig. 5.2**) arising from different time scales underlying the quadratic energy spectrum of this system.

(U. Roy, J. Banerji and P. K. Panigrahi)

Sub-Planck-scale Structure in Molecular Wave Packets

We demonstrate the possibility of realizing sub-Planck-scale structures in the mesoscopic superposition of molecular wave packets involving vibrational levels. The time evolution of the wave packet, taken here as the SU(2) coherent state of the Morse potential describing hydrogen iodide molecules, produces macroscopic-quantum-superposition-like states, responsible for the above phenomenon. We investigate the phase-space dynamics of the coherent state through the Wigner function approach and identify the interference phenomena behind the sub-Planck-scale structures. The optimal parameter ranges are specified for observing these features. This work is done in collaboration with A. Chiruvelli.

(S. Ghosh, J. Banerji and P.K. Panigrahi)

Revival Dynamics of Diatomic Molecular Wave Packets

We study the revival and fractional revivals of a diatomic molecular wave packet of circular states whose

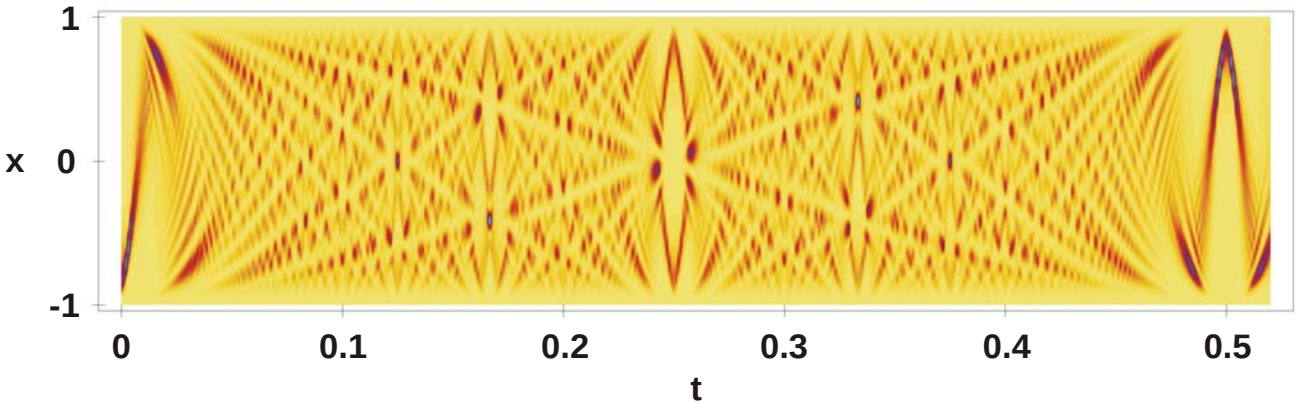


Fig. 5.2 A quantum carpet displaying the revival dynamics of a coherent state of the Pöschl-Teller potential

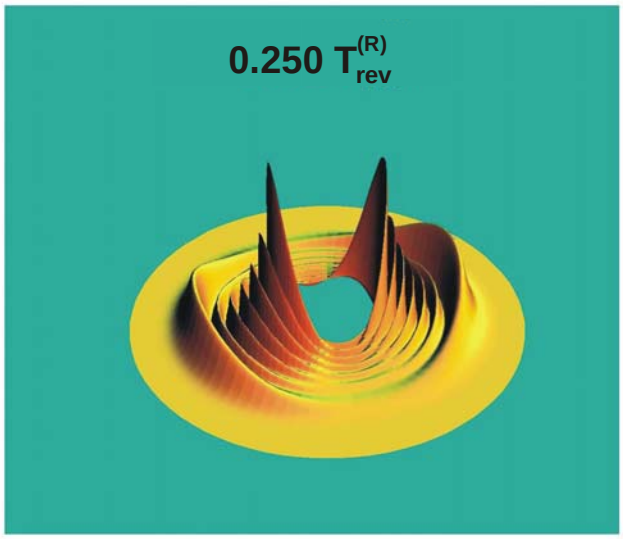


Fig. 5.3 Ro-vibrational fractional revival of a Hydrogen molecular wave packet.

weighing coefficients are peaked about a vibrational quantum number ν_0 and a rotational quantum number j_0. Furthermore, we show that the interplay between the rotational and vibrational motion is determined by a parameter $\gamma = (D/C)^{1/2}$, where D is the dissociation energy and C is inversely proportional to the reduced mass of the two nuclei. Using I_2 and H_2 as examples, we show, both analytically and visually (through animations), that for $\gamma >> \nu_0, j_0$, the rotational and vibrational time scales are so far apart that the ro-vibrational motion gets decoupled and the revival dynamics depends essentially on one time scale. For $\gamma \sim \nu_0, j_0$, on the other hand, the evolution of the wave packet depends crucially on both the rotational and vibrational time scales of revival. In the latter case, an interesting ro-vibrational fractional revival **(Fig. 5.3)** is predicted and explained.

(J. Banerji and S. Ghosh)

Light Scattering in Cooper-paired Fermi Atoms

We have carried out a detailed theoretical study of light scattering off Cooper-paired Fermi atoms at zero temperature. We have developed a field-theoretic formalism for polarization-selective light scattering (PSLS) which, in general, allows for unequal energy and momentum transfer to the two partner atoms of a Cooper-pair. In optically trapped ^{6}Li atoms with two hyperfine spin components near a magnetic field Feshbach resonance, PSLS can lead to single-particle excitations of one spin-component only. This may have experimental implication in detecting pairing gap. A small difference in momentum transfers to the two spin-components may be useful in exciting Anderson-Bogoliubov phonon mode of symmetry breaking.

(B. Deb)

Study of Smoke Aerosols by using Dynamic Light Scattering

Particle size is a very important physical parameter that determines the dispersion of particles and hence their effect on health, visibility and climate. In the present study we used photon correlation technique to study the effects of concentration and temperature on the size of cigarette smoke aerosols. We found that size increases almost linearly with an increase in concentration but decreases with an increase in temperature. The study holds importance because laboratory studies of aerosols under controlled conditions can be quite useful in modeling atmospheric aerosols.

(R. P. Singh, V. K. Jaiswal and V. K. Jain)

Wigner Distribution Function of an Optical Vortex

Looking at the varied applications of optical vortices, the study of their coherence properties becomes very important. Study of the Wigner distribution function (WDF) can be quite useful for this purpose since it can provide coherence information in terms of the joint position and momentum (direction) phase space distribution of the optical field. We produce an optical vortex by a computer generated hologram (CGH) and find its Wigner distribution function using a shearing Sagnac interferometer. Experimental observations agree with our analytical expression for the Wigner function obtained for an optical vortex.

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

Aerosol Properties over Delhi and their Implications to Short Wave Radiative Forcing

Measurements of physical and optical properties of aerosols were made at Delhi, during December-2004 as part of the ISRO-GBP's Land Campaign-II. The average clear sky aerosol optical depth (AOD) is found to be 0.91±0.48, which is much higher than the AOD value reported for most other cities in India during this season of the year. Further, a large increase in AOD on hazy and foggy days is found at all wavelengths and the percentage increase in AOD at shorter wavelengths is higher on hazy days compared to on clear days.Diurnally averaged black carbon mass concentration is about 15 μgm^{-3} during clear days and about 65 μgm^{-3} on hazy days. Wavelength dependency in aerosol absorption shows signatures of presence of significant amount of absorbing aerosols produced from biofuel/biomass burning. Single scattering albedo at 525 nm is found to vary between 0.6 and 0.8. Lidar observations reveal that during fog event there is a subsidence of aerosols to an extremely dense and shallow atmospheric layer of less than 200 m height from the surface. We find a large negative aerosol radiative forcing in the range of -40 to -86 Wm^{-2} depending on clear, hazy or foggy condition, while forcing at the top of the atmosphere varied only between -2 and +3 Wm^{-2} indicating that there is a large trapping of radiation energy within the atmosphere, which is comparable to the radiative forcing at the surface level.

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

Aerosol Size Distribution and its Impact on Radiative Forcing

Aerosol mass concentration and size distribution along with AOD spectra were measured over Hisar during the month of December 2004 as part of the ISRO-GBP land campaign II. Heavy fog conditions were encountered during 12th,13th and 14th December. Before the foggy period the surface level aerosol mass concentration was about 95 μgm^{-3} while during foggy days the values went up to 231 μgm^{-3} and after the foggy period the value was about 103 μgm^{-3}. Prior to foggy days mass of nucleation mode aerosol (size less than 0.1 μm) was higher while during and after the foggy period the accumulation mode aerosol was found to dominate. The AOD was 0.34 ±0.1 at 500 nm before foggy days while it was 0.66 ±0.3 during foggy days and 0.46 ± 0.1 after the foggy period. During foggy period the AOD showed large variation due to rapidly changing relative humidity. With the help of Optical Properties of Aerosols and Clouds (OPAC) model, measured AOD values are fitted with the model calculated AOD values by choosing proper combination of aerosol components, viz., water soluble (WS), insoluble (IS), soot (SO) and mineral dust (MD). During the entire measurement period the dominating components are found to be WS and SO. It is found that during foggy days the instantaneous aerosol shortwave radiative forcing at the surface varied from -10Wm^{-2} during early morning hours to about -80Wm^{-2} during noon hours.

(Sanat Kumar Das and A. Jayaraman)

Aerosol Radiative Forcing over a Continental Polluted Location in North India

From the simultaneous measurements of aerosol optical, physical and chemical characteristics over Hisar, a semi-urban location in northern India, aerosol radiative (shortwave (SW), longwave (LW) and net) forcings are estimated using a radiative transfer model. SW atmospheric (ATM) forcing is found to increase from 16 Wm^{-2} during clear periods to 49 Wm^{-2} for foggy days (**Fig. 6.1**). LW cooling of the ATM increases from about -2 Wm^{-2} for clear conditions to about -3 Wm^{-2} during foggy period.

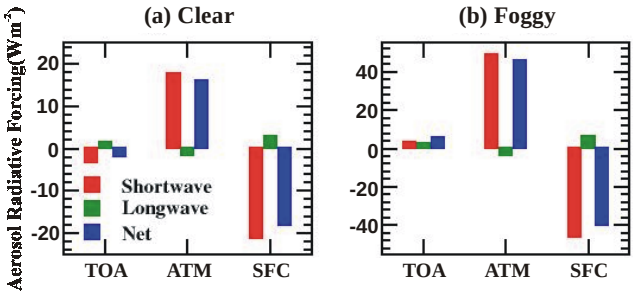


Fig. 6.1 Shortwave, longwave and net clear-sky aerosol radiative forcings for clear (a) and foggy (b) conditions at the top of the atmosphere (TOA), atmosphere (ATM), and surface (SFC) over Hisar during December 2004.

LW ATM forcings are found to contribute 11-14% to the net ATM forcing. As the LW ATM forcings are negative they can partially cancel the large SW ATM warmings. Sensitivity study shows that LW ATM cooling becomes more prominent with an increase in the amount of absorbing aerosols and decrease in water vapor, while LW forcings are found to vary only by 1% for differing ozone amounts.

(S. Ramachandran, R. Rengarajan, A. Jayaraman, M.M. Sarin and Sanat K. Das)

Study of MODIS Derived AOD over Indo-Gangetic Plain

The purpose of the study was to examine the efficiency of satellite sensors for aerosol remote sensing under heavy fog conditions over the Gangetic plain during December 2004. The MODIS derived Aerosol Optical Depth, averaged on a $0.5^{o}X0.5^{o}$ scale over the region extending from $32^{o}N$, $72^{o}E$ to $20^{o}N$, $96^{o}E$, shows regions of high values shifting eastwards during the period of study. This is a combined effect of transport of particles from the western region of the country as well as due to hygroscopic growth of the existing aerosol particles under high humidity conditions.

(Amit Misra and A Jayaraman)

Black Carbon Aerosol Mass Concentrations over Ahmedabad

Black carbon (BC) aerosol mass concentrations at seven wavelengths (370-950 nm), measured over Ahmedabad from September 2003 to June 2005 show diurnal variation with two peaks in the morning and in the late evening hours, due to fumigation effect of boundary layer, gradual increase in the anthropogenic activities and rush hour traffic. January BC values are about a factor of 5 higher than July values due to a shallow boundary layer. In July an increase in boundary layer height, surface temperature, convective activity and rainfall result in lower BC values. January-February BC mass concentrations are higher over Ahmedabad (9-10 $\mu g\ m^{-3}$) than over Trivandrum, where BC is about 8 $\mu g\ m^{-3}$, over central India and Hyderabad and over various locations in Europe.

(S. Ramachandran and T.A. Rajesh)

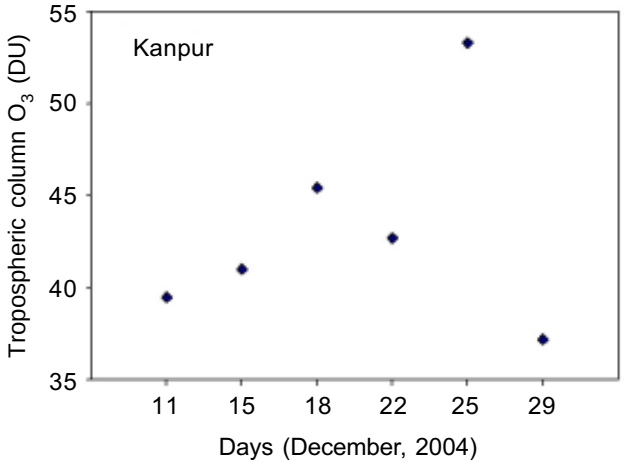
Characterization of Sources of Ozone and Related Gases at Hisar and Kanpur during December 2004

Continuous measurements of surface O_3, CO, NOx were made at Hisar and Kanpur by PRL as a part of the ISRO-GBP land campaign conducted during December 2004. Additionally, air samples collected in glass bottles, twice a day were analysed at PRL for various C2-C5 Non-Methane Hydrocarbons (NMHCs). Time series distributions showed large variations in trace gases during clear days while these subsided during foggy days. During clear sky days the mean mixing ratios of O_3, CO and NOx were 31 ppbv, 581 ppbv and 16 ppbv, while during foggy days these were 13 ppbv, 558 ppbv and 8.5 ppbv, respectively. Lower ozone levels during foggy period are mostly due to non-availability of solar radiation for photochemical production. The CO/NOx ratio at Hisar was ~35 ppbv/ppbv, which compares fairly well with other reported measurements near biomass and biofuel burning sources, while these are much higher than ratios of 5-10 ppbv/ppbv observed due to fossil fuel combustion. Other NMHCs ratios and interspecies correlations confirm that the distributions of primary pollutants are controlled by biomass burning and biofuel combustion both at Hisar and Kanpur.

(L. K. Sahu, S. Venkataramani , T. A. Rajesh, K. S. Modh and S. Lal)

Vertical Distribution of Tropospheric Ozone over Kanpur

Six balloon flights were made to study the vertical distributions of ozone, temperature, water vapor and winds using standard ECC ozonesonde, radiosonde and global positioning system (GPS) respectively from the campus of IIT Kanpur during December 2004 as a part of the ISRO-GBP land campaign. Ozone mixing ratios were extremely high (about 30 ppbv higher than from the average ozone for the month) in the altitude range of 10 km to 16 km on December 25. The average tropospheric content of ozone, which is obtained by integrating individual profiles up to tropopause height (~ 17 km), is about 45 DU but on 25 December 2004, it was found to be excep-



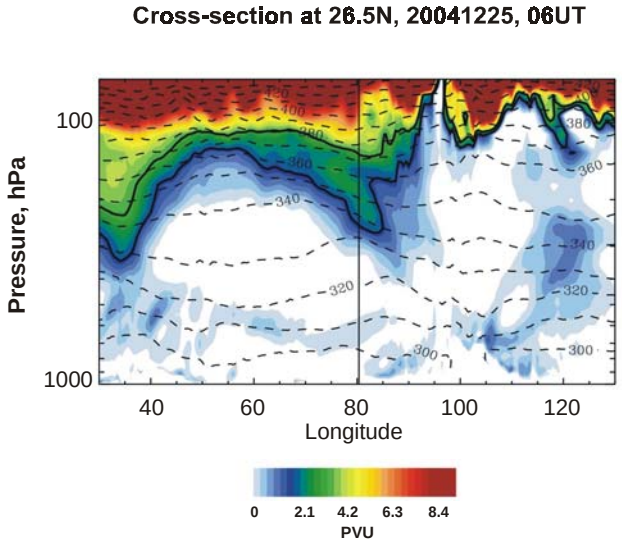


Fig. 6.2 (top) Total tropospheric column ozone derived from balloonborne ozone sonde flights conducted from Kanpur, (bottom) Potential vorticity from ECMWF data.

tionally higher (~54 DU) (**Fig. 6.2a**). The potential vorticity data taken from ECMWF (European Centre for Medium-Range Weather Forecast) indicate intrusion of stratospheric air in the upper troposphere on December 25, at this site (**Fig. 6.2b**).

(Shilpy, S. Venkataramani, T. A. Rajesh, Y. B. Acharya and S. Lal)

Long Range Autocorrelations in Atmospheric Ozone

Detrended Fluctuation Analysis (DFA) is a new and promising method to analyze nonlinear and non-stationary signals of atmospheric phenomena. The DFA procedure is applied to time series of daily Total Columnar Ozone (TOZ) for 15-20 stations all over the world. The data for the period 1979-2003 are taken from Total Ozone Mapping Spectrometer (TOMS) aboard the two satellites Nimbus and Earth Probe. From the original time series, a running sum of the fluctuations from the mean is considered. The new time series is divided into non-overlapping intervals of equal length, n. In each interval, we fit a straight line. The detrended square variability, F(n) is then calculated, of which the power law behaviour $F(n) \propto n^a$ is extracted. For most stations long range correlation (persistence) is observed (i.e. $0.5 < \alpha < 1.5$) upto one year time scales for the period 1979-1992, after which short-range correlation can be seen (anti-persistence) (**Fig. 6.3**). However, long range correlation upto 2 years is observed for the period of 1996-2003.

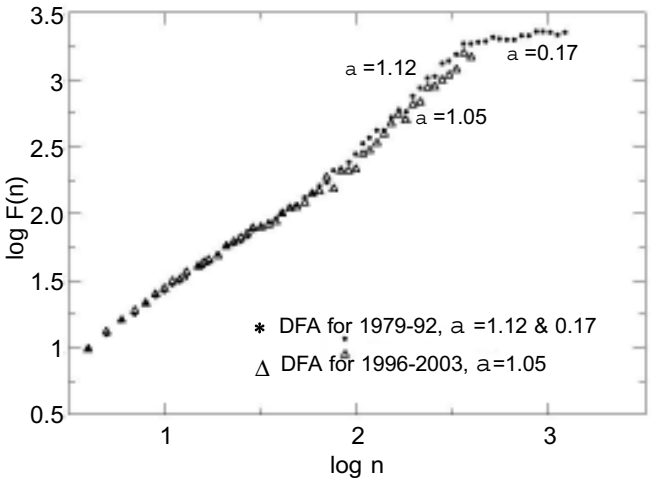


Fig. 6.3 Detrended Fluctuation Analysis (DFA) of total columnar ozone at Jungfrau, Switzerland reveals long range correlation for the period 1979-92 and 1996-03.

(Varun Sheel)

Installation and Testing of CAM 3.1 General Circulation Model at PRLSP

Community Atmosphere Model (CAM) version 3.1 developed at National Center for Atmospheric Research (NCAR), USA is installed on PRLSP machine. Presently, we are able to run the model using distributed memory

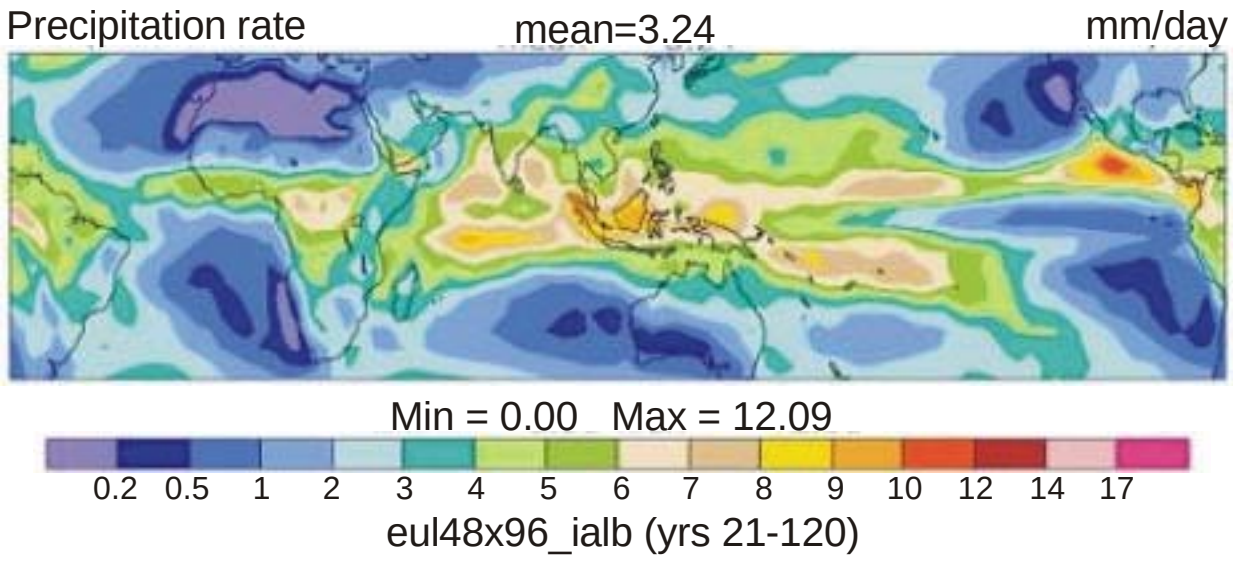


Fig. 6.4 Annual mean precipitation rate simulated at PRL using the model of NCAR. USA.

parallelisation with 4 processors. We have carried out the Perturbation Growth Test (PGT) and compared the model output with similar simulation on NCAR machine. The result from the PGT shows that the RMS temperature difference is within $2x10^{-10}$ for 72 hour simulation and the result is comparable with that of NCAR simulation. Annual mean precipitation rate has been simulated using this model (**Fig. 6.4**) and the results are compared with trusted model simulations at NCAR. Excellent match is found between them.

(H. Gadhavi, J. Raval and A. Jayaraman)

Lidar Investigation of Difference in Middle Atmospheric Thermal Structure

The general characteristic of middle atmospheric thermal structure is being studied using Rayleigh lidar observations from Mount Abu. The data for the period 1998-2001 are compared with that obtained from Gadanki. The stratopause height and temperature over both stations show a wide variation with a mean value of about 48 km and 263 K respectively. The monthly variations of stratopause height and temperature at both stations reveal prominent semi-annual trend. The monthly occurrence percentage of double stratopause also show a semi-annual trend with peaks during March/April and October/November months. Though Mesospheric Temperature Inversion (MTI) has been found at both the stations, the MTI altitude is higher over Gadanki than at Mount Abu.

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

Plasma Density Irregularities Produced due to Neutral Turbulence

Spectral measurements of electron density fluctuations in the scale size range of one meter to a few kilometres made by a rocket-borne Langmuir probe, showed the presence of irregularities in 67.5 -71 km and 79 -89 km regions. The irregularities in the lower region were having the scale sizes of more than a few metres and had amplitudes in the range of a few percent of the ambient density, while in the upper region the scale sizes were as small as a metre and had amplitudes less than a percent. Based on their spectral characteristics, these irregularities were suggested to be produced by neutral air turbulence. The irregularities in the upper region (79 - 89 km) were also detected by the MST radar at Gadanki (**Fig. 6.5**). These results show that the horizontal extent of turbulent layers could be 100 km or even more.

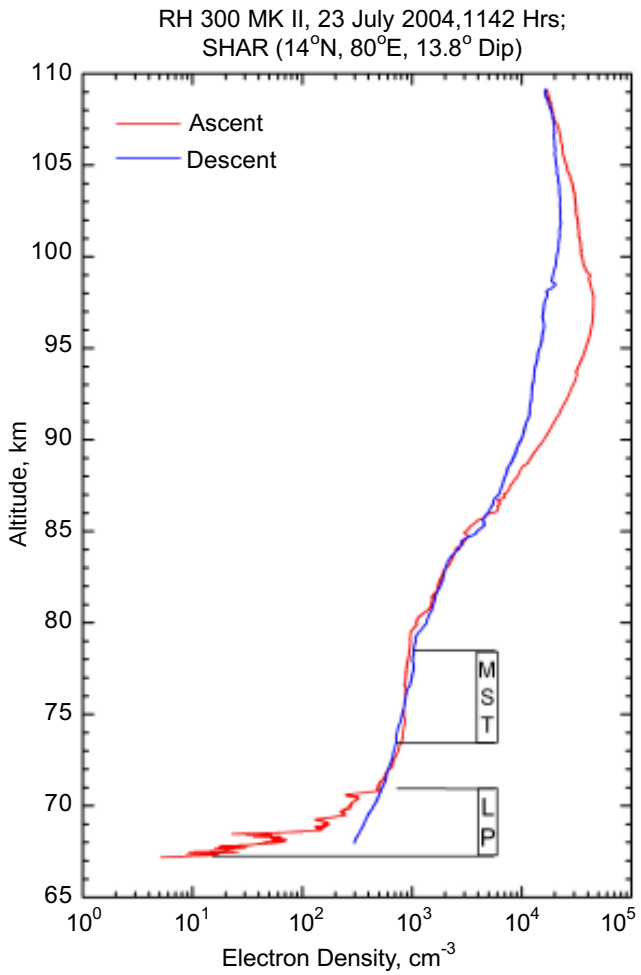


Fig. 6.5 Regions of electron density structures as observed by rocket borne Langmuir probe and MST radar.

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

Nightglow Emissions in the MLT region

Atomic oxygen green line emission at 557.7 nm over Thumba has been modelled to estimate the amount of emission to be expected for the multi-wavelength photometer experiment Abha. Profiles of total neutral density [M], [O], [O_2], [N_2] and temperature were generated using the MSIS E-90 model. The peak of the emission layer falls at 96 ± 1 km almost coinciding with the peak of the atomic oxygen (O) density at 97 ± 1 km. The simulated 557.7 nm emission varies as $[O]^3$ below the peak and as $[O]^2[M]$ above the peak. The simulation showed that the emission increases very rapidly towards midnight and then slowly decreases towards dawn.

(Uma Kota and H. S. S. Sinha)

Characteristics of Plasma Depletions

Characteristics of ionospheric plasma depletions were studied by simultaneously employing the techniques of optical imaging, phase scintillations of GPS TEC signals and ionosonde, during solar maximum epoch. The imaging observations were taken from Kavalur using PRL's multiwavelength imager working at 557.7, 630 and 777.4 nm. The GPS total electron content phase scintillations were estimated using International GPS Service (IGS) station at Bangalore. The background ionospheric parameters were estimated using the ionosonde at Thumba. Intense and continuous occurrence of plasma depletions was observed during February - March 2002, with post-midnight generation of depletions in the field of view of the imager during several nights. Unlike the case of pre-midnight depletions, there was no upward motion of the F-layer prior to the generation of post-midnight depletions. The post-midnight depletions become well developed after about 40 min of their first appearance as weak structures in airglow images. These depletions have narrow widths, smaller phase fluctuations and are weaker as compared to the pre-midnight depletions. This work was done in collaboration with National Central University, Chung-Li, Taiwan.

(H.S.S. Sinha, S.B. Banerjee, R.N. Misra, N. Dutt and M.B. Dadhania)

Development of Equatorial Spread-F Controlled by a Space Weather Event

An Equatorial Spread F (ESF) event was detected by the Indian MST radar and a collocated airglow photometer (measuring OI 630.0 nm airgow) on January 7, 2005 at Gadanki. It is found that the ESF event got triggered during the pre-midnight hours (**Fig. 6.6**) by the rapid ascent of the equatorial F layer brought forth by the southward turning of the Z-component (B_z) of the Interplanetary magnetic field measured by the Advanced Composition Explorer (ACE) satellite. The VHF radar structure

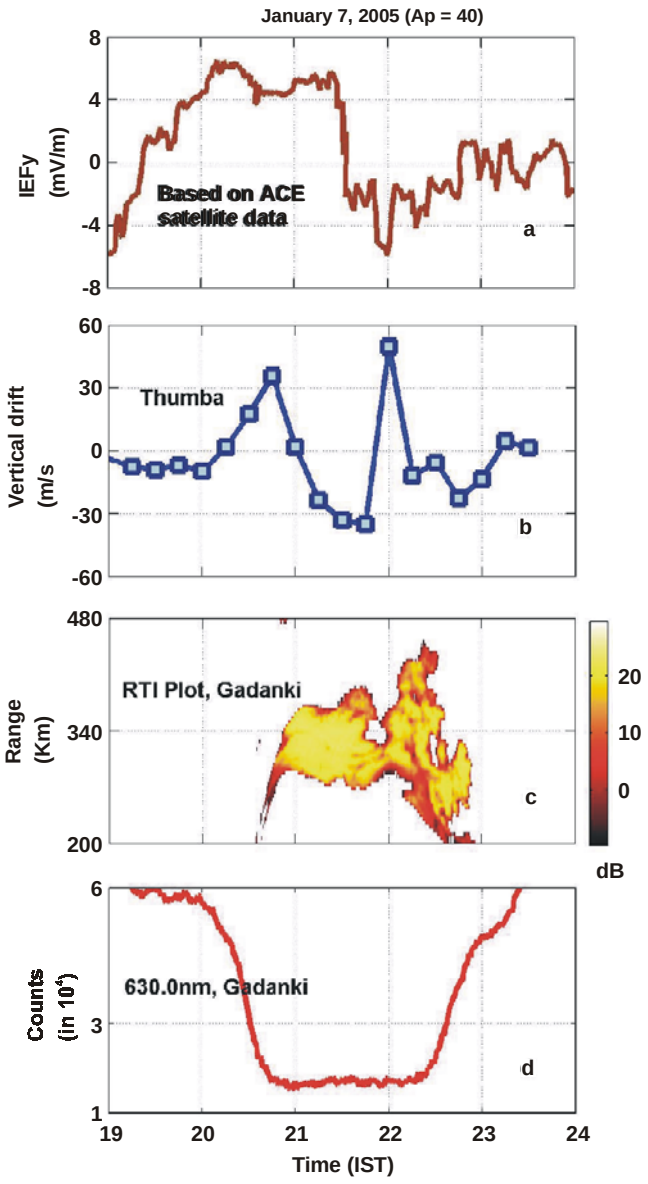


Fig. 6.6 (a) Y component of Interplanetary Electric field (IEFy) measured by ACE satellite, (b) vertical drift velocity over Thumba, (c) Range-Time-Intensity plot of ESF irregularities as observed by the Indian MST Radar, (d) OI 630.0 nm airglow intensity variation observed by the narrow-band airglow photometer of PRL.

was characterized by an overall bottom side modulation with an up-drafting plume structure during the later phase of ESF. It is found that the development of this plume structure is associated with the "sudden" northward turning of the B_z. This work is done in collaboration with NARL, Gadanki and SPL, VSSC, Thiruvananthapuram.

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

Pre-seeded Structure in Triggering of Plasma Plumes during Space Weather Events

A few case studies involving the reversal of nighttime zonal electric field to eastward over equatorial region due to the effects of geomagnetic storms are discussed. In some of the cases, these alterations lead to the development of plume structures associated with ESF. In another case, the ESF was found to be absent. Based on the modeling investigation carried out previously, it is argued that though storm-time eastward electric field is a necessary condition, but not a sufficient condition for the development of the pre-midnight plume structure. The importance of the pre-seeded structure for the development of pre-midnight plume event is brought out from these studies.

(R. Sekar and D. Chakrabarty)

Plasma Irregularity Structures during Equatorial Spread-F Events

Simultaneous observations, using the Indian MST radar and a collocated airglow photometers (operating at 630.0nm and 777.4nm) were conducted during January - March 2003 to 2006, to study electron density structures, associated with ESF in 250 km region and the peak of the F region. These observations, which were made in bi-directional mode (zenith and east), revealed special ESF structures such as, wavelike and flat type bottom side structures, vertically extended plumes and plasma enhancements. In addition to these, the optical observations also detected the presence of whirl- like plasma flow pattern during an ESF event, as shown by nonlinear numerical simulation studies. The plumes as well as the bottom side structures, observed by optical technique, are in conformity with the small and large scale structures associated with the ESF. This work was carried out in collaboration with NARL, Gadanki.

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

Martian Global Ionosphere at High Latitudes

Electron density profiles in the altitude range of

115-220 km were computed with a resolution of 100 m at every 5° longitude interval, for 0° to 360° longitude, in a latitude range of 50°N to 70°N in the Martian ionosphere. The total neutral density measured by the accelerometer experiment onboard the Mars Global Surveyor (MGS) spacecraft were used in these calculations. Using the known mixing ratios, the densities of five major neutral constituents, viz., CO_2, N_2, O_2, O and CO were calculated for the dayside of the Martian atmosphere. The electron density profiles were then calculated using Analytical Yield Spectrum (AYS) approach alongwith the X-ray (1-9 nm), EUV (9-102.5 nm) flux incident at 80° zenith angle in the Martian atmosphere and the known photochemistry. The calculated electron density profiles showed the existence of a primary peak and a secondary peak. These profiles were then compared with the electron density profiles measured by a radio occultation experiment onboard the MGS spacecraft (**Fig. 6.7**). It is found that the calculated amplitude of both the primary and the secondary peaks matches very well with the observations. There is, however, a fixed phase difference in the calculated and observed peaks (both primary and secondary). This phase difference corresponds exactly to the time difference between the observations of neutral density by the accelerometer experiment and electron density by the radio occultation experiment.

(S. A. Haider and V. R. Choksi)

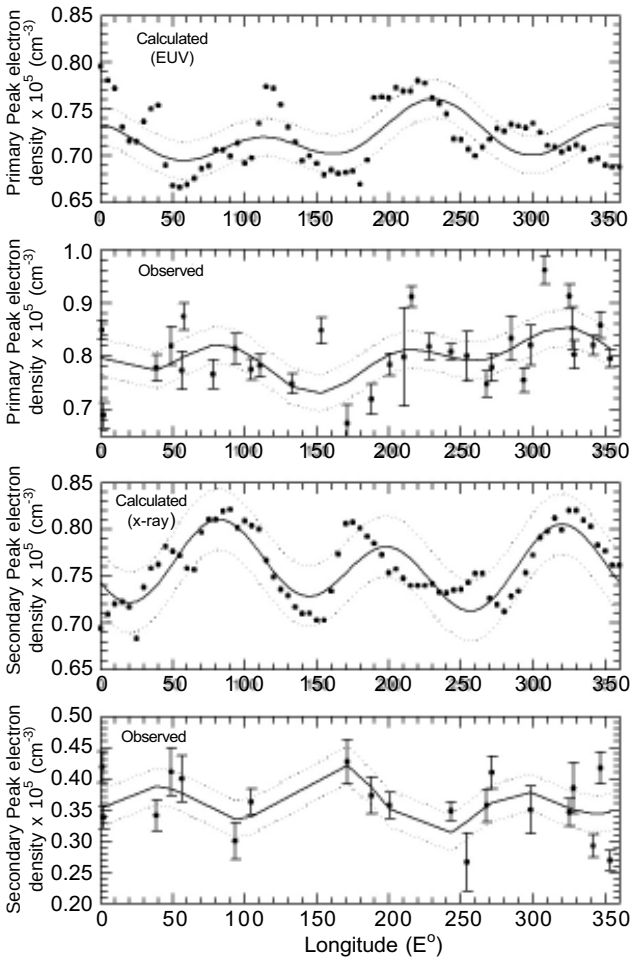


Fig. 6.7 Longitudinal variability of primary and secondary peak electron densities in Mars produced by photoionization and photoelectron impact ionizations respectively at latitude range of 50-70N.The measured primary and secondary peak electron densities are also shown in this figure.Solid lines indicate the best fit, dotted line represents 0.95 confidence limits and vertical bars show measurement errors.

Solar Wind Electron Impact with Cometary Atmosphere

Density profiles of nine major ions due to absorption of solar EUV and solar wind electron in the atmosphere of Comet Halley have been calculated. The density of these ions lies between 10 and 10^4 cm^{-3}. Twelve gases in the model atmosphere were used. The overall effect of solar wind electron impact ionization source on the density is to increase its magnitude by ~ 50 % at distance > 100 km and to about a factor of two or more in the region very close to the nucleus. The total ion density is compared with Giotto measurement. The density of minor ions lies between 10^{-1} and 10^2 cm^{-3}. The production rates, loss rates and chemistry of 26 ions are discussed in detail to study the abundances of cometary nucleus and the role of solar wind impacting on them.

This work is done in collaboration with Space Physics Laboratory, VSSC, Trivandrum.

(S. A. Haider)

Electron Impact Dissociation of Polyatomic Molecules

Fragmentation pattern of polyatomic molecules when bombarded with 1.3 keV electrons was investigated by ion momentum spectroscopy with multi-coincidence ion detection. Using covariance mapping of the time-of-

flight of two ions formed in a single ionization event, different fragmentation pathways were identified, and estimates made of the precursor molecular ion states. Using isotopically different, but chemically identical samples, active sites in rearrangement of H- bonds in dissociation of ethanol were identified. Rearrangement of H atoms requiring the breaking of the O-H bond is found to have a larger role in the formation of H_3^+ radical than the hydrogen atoms on the carbon sites.

In a related study, a rigorous assessment of the values of the mean kinetic energy based on the variance of the time-of-flight distributions of ions was made using momentum spectrometer built in house. The variance of the time-of-flight distribution is shown to be a more robust estimate of the mean kinetic energy, as opposed to the commonly used estimate based on the square of the FWHM.

(B. Bapat and Vandana Sharma)

Photo-triple-ionisation and Fragmentation of Carbon-dioxide

In an experiment involving detection of a photoelectron and up to three photoions from CO_2 in coincidence, we have observed the break-up of CO_2^{3+} into an ion triple viz. $[C^+:O^+:O^+]$ or ion pairs $[C^{2+}:O^+]$, $[O^{2+}:C^+]$, $[O^{2+}:O^+]$. From an analysis of the coincidence pattern, four decay modes of the CO_2^{3+} ion are postulated (**Fig. 6.8**). Kinetic energy release in the channel leading to $[C^+:O^+:O^+]$ is measured and is postulated to arise from four precursor states. This work is done in collaboration with Raja Ramanna Centre for Advanced Technology, Indore.

(R. K. Singh, Vandana Sharma, I. A. Prajapati, K. P. Subramanian and B. Bapat)

Comparison of Molecular Fragmentation under Electron and Ion Impact

Electron projectiles perturb molecular targets weakly, compared to equivelocity highly charged ions. In order to study the similarities and contrasts in these two cases, fragmentation of CO, CO_2, SF_6 and CCl_4 molecules was studied using 1.3 keV electron beam (at PRL)

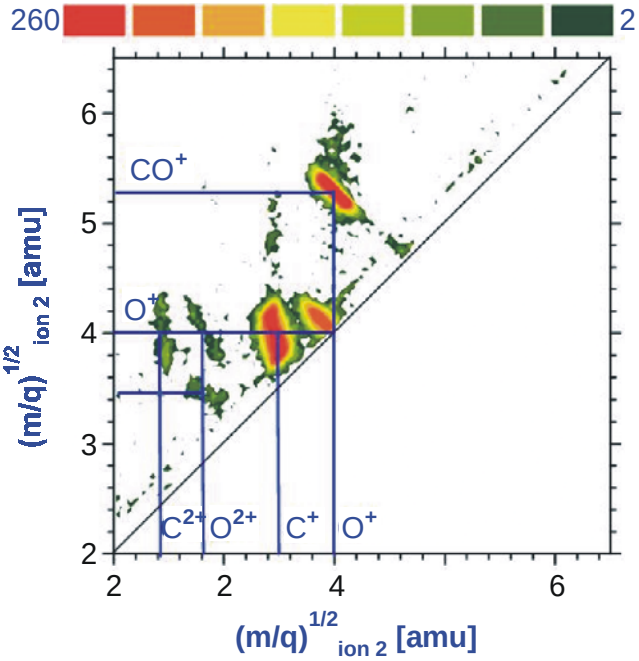


Fig. 6.8 The covariance map of ion pairs formed by photofragmentation of CO_2 molecule by 200 eV photons, showing $[O^+:CO^+]$, $[C^+:O^+]$, $[O^+:O^+]$, $[O_2^+:O^+]$, $[O_2^+:C^+]$ and $[C_2^+:O^+]$ coincidences.

and 150 keV Ar^{8+} beam (at Nuclear Science Center, New Delhi). A larger number of fragmentation pathways originating from multiple-charged and excited precursors were seen in case of ion perturbation. Large deviations from expected kinetic energy distributions were attributed to internal excitation of the precursor molecular ion. This work is done in collaboration with Nuclear Science Center, New Delhi.

(B. Bapat and Vandana Sharma)

Effects of Laser Fluence and Ambient Pressure on Laser-blow-off Plasma

Time and space resolved emission profiles of C II ionic line from the laser blow off (LBO) plumes of multilayered LiF-C thin film have been investigated using laser induced forward transfer technique. The evolution features of 426.7 nm line were studied in different ambient environment ranging from high vacuum to 3 mbar of argon and at various fluences of the ablating laser. The

expansion dynamics of a LBO plasma was found to behave differently from the conventional laser produced plasma (LPP) as regards free expansion, plume splitting, compression and hydrodynamical instability. The validity of Rayleigh-Taylor instability, shock wave and drag force model in the present experimental condition has been investigated. This work is done in collaboration with Institute of Plasma Research, Gandhinagar.

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

Dynamics of Laser Produced Plasma

The effect of atomic mass in the evolution dynamics of laser produced plasma was studied in aluminium, copper and lead plasma plumes. The transient pulse profile at various distances in the plume due to neutral emission lines was analyzed using multicomponent shifted-Maxwell-Boltzmann (SMB) distributions. The expansion velocities were measured using time-of-flight technique. It was observed that at low ambient gas pressures, the expansion velocity decreased as the atomic mass of the plume constituent increased. At higher pressures, reverse trend was observed which is explained by a ballistic model. Contrary to the expectation, it was observed that at high ambient pressures, the ejected material did not homogenize. The drag model was suitable to explain the expansion at low pressures (< 1 mbar), whereas the shock model was required to explain the evolution dynamics at high pressures.

(B. G. Patel, K. P. Subramanian, I. A. Prajapati and G. N. Dar)

The research activities of the division have mainly focused on delineating processes and time scales related to early solar system, lunar surface and earth's lithosphere, hydrosphere, biosphere and atmosphere. Some new techniques and experimental approaches have also been developed. Selected research activities are described in the following.

Lithium Isotopic Composition in Early Solar System Solids

The presence of ^{10}Be (half-life = 1.5 Ma) in early solar system suggests interaction of solar energetic particles (SEP) with solar nebula matter as the plausible source of this nuclide as ^{10}Be is not a product of stellar nucleosynthesis. However, the possibility of galactic cosmic ray ^{10}Be also being a source cannot be ruled out. A hint for excess ^{7}Li, a decay product of ^{7}Be (half-life = 53 days), in a meteoritic Ca-Al-rich refractory inclusion (CAI) that formed very early in the solar system has been claimed recently by a group of scientists from US and France. A confirmation of this hint will uniquely establish the role of SEP production of short-lived nuclides in the early solar system as the extremely short half-life of ^{7}Be precludes other possible sources. We have analysed CAIs from the Efremovka meteorite to look for ^{7}Li excess. Melilite in CAIs, that are free from secondary perturbations, were analyzed for Li-Be isotope records using a Cameca ims-4f ion microprobe. The analyzed CAIs host records of the short-lived nuclide ^{26}Al (half-life = 0.72 Ma). The results obtained so far do not provide any evidence for resolved ^{7}Li excess that can be attributed to ^{7}Be decay and thus are at variance with the recent claim. Further, the inferred initial ^{7}Li/^{6}Li ratios in the CAIs are lower than the standard reference value. This may imply heterogeneity in Li isotopic distribution in the protosolar cloud that did not undergo complete mixing and homogenization at the time of CAI formation.

(M. P. Deomurari and J. N. Goswami)

Onset and Duration of Chondrule Formation in the Early Solar System

We have studied fossil records of ^{26}Al, that decays to ^{26}Mg, in chondrules from the Semarkona (LL3.0) meteorite that has suffered extremely low degree of thermal metamorphism in its parent body and is expected to retain pristine records of Al-Mg isotope systematics. We have identified chondrules containing Al-rich phases (glassy mesostasis and rare plagioclase) using SEM and EPMA techniques and carried out isotopic studies of a dozen selected chondrules. We could detect ^{26}Mg excess (from ^{26}Al decay) in four chondrules. Three of these are characterized by initial ^{26}Al/^{27}Al ratio of ~10^{-5}, while the value for the fourth chondrule is ~5×10^{-6} at the time of their formation.

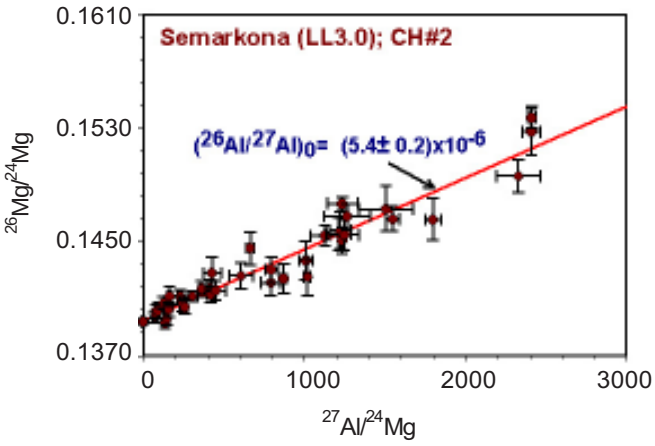


Fig. 7.1 ^{26}Al-^{26}Mg isochron in a Semarkona chondrule.

The initial ^{26}Al/^{27}Al ratios obtained in this study reinforce the suggestion that formation of CAIs preceded chondrule formation by at least 1.5 Ma. Further, the very similar initial ^{26}Al/^{27}Al ratios in three of the chondrules argues for a short duration of chondrule formation. However, the effective formation time of the fourth chondrule, that has a very well behaved Al-Mg isotope systematic (**Fig. 7.1**), has to be ~ 0.7Ma later than the other chondrules and suggest an extended duration of chondrule formation unless we invoke thermal metamorphism of such chondrules in a pre-parent body setting. Work done in collaboration with Geological Survey of India, Kolkata.

(N. G. Rudraswami and J. N. Goswami)

Noble Gases in Individual Chondrules and Implications for their Formation

A systematic study of noble gases in individual chondrules from different classes of chondrites has been

initiated to understand the chondrule formation process. Noble gases in chondrites and chondrules are generally a mixture of trapped and cosmogenic components and these can be resolved by standard procedures. In almost all chondrules, trapped Ne and Ar are derived from two different components, Q and HL, with the Q source being the dominant. In chondrules with high amount of Q gases, we observed metal sulfide, attesting to the suggestion that the abundance of metal sulfide in chondrules is linked to the amount of Q-Ar in them. We also observed solar like signatures in some porphyritic chondrules. Abundances of cosmogenic ^{3}He, ^{21}Ne and ^{38}Ar are comparable to that in the respective host meteorites.

(J.P. Das and S.V.S. Murty)

Sources of Excess Nitrogen in Lunar Soils: Clues from Lunar Meteorite Y983885

Most of the trapped noble gases and nitrogen in lunar soils are of solar wind origin. However, the order of magnitude higher abundance of N in lunar soils compared to solar abundances, and over 30% variation in δ^{15}N is still not well understood. We have analysed two samples of the Antarctic lunar meteorite Y983885 (from different locations) for N and noble gases. Y983885 is unique as it has the largest amount of solar wind noble gases among the lunar meteorites and ^{14}N/^{36}Ar ratio about 10 times more than that expected for solar wind, similar to that in lunar soils. Stepwise temperature pyrolysis data for these samples show a δ^{15}N profile typical of lunar soils. Release profile of ^{14}N/^{36}Ar also shows similar pattern (**Fig. 7.2**), with ^{14}N/^{36}Ar values upto ~80000 at low temperature, a plateau value of ~ 360, similar to lunar soils at intermediate temperatures followed by higher values at melting temperatures. The release pattern of ^{14}N/^{36}Ar can be interpreted in terms of continuous addition of almost pure non-solar N (devoid of noble gases) as a surface component. During subsequent gardening of the lunar surface by micro-meteorite impacts, this excess N gets intimately mixed with the SW component, and behaves similar to it during thermal release. The most recently added excess N, however, remains only weakly bound on the surface and is released at a lower temperature (than SW) during pyrolysis. The δ^{15}N of the low temperature release, with its characteristic high ^{14}N/^{36}Ar, could be close to the isotopic signature of excess N.

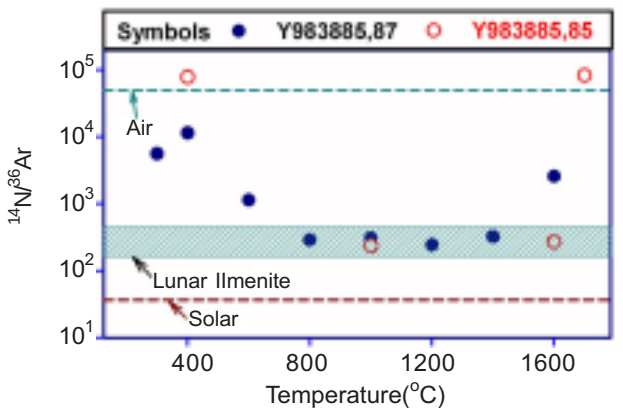


Fig. 7.2 Release pattern of ^{14}N/^{36}Ar ratio in two samples of lunar meteorite Y983885. ^{14}N/^{36}Ar value of Air, solar component as well as the range observed for lunar soils are also shown in the plot.

It is proposed that the influx of interplanetary dust particles (IDP) that are continuously bombarding the lunar surface and are rich in organics and have positive δ^{15}N could explain the observed feature. On impact, the volatalised N (from IDP) gets deposited on the surface grains and with time becomes more firmly integrated into the grain due to gardening and behaves similar to SW component during thermal release.

(R. R. Mahajan and S. V. S. Murty)

Noble Gas Components in Indian Carbonatites

Noble gas studies have been conducted in five carbonatites, from Hogenakal (2400 Ma), Sevattur (770 Ma) and Khambamettu (523 Ma) from southern Peninsular India, Sung Valley (107 Ma) associated with the Assam-Meghalaya Plateau in eastern India and Ambadongar (65 Ma) associated with the Deccan flood province. Our study shows that noble gases in carbonatites are a mixture of trapped and in situ produced components. In the younger carbonatites from Ambadongar and Sung Valley, the in situ component is

very minor, allowing resolution of the trapped component (for He, Ne) into those of depleted mantle (DM) and a lithospheric mantle component, introduced during ancient subduction process. The Ar and Xe isotopic signatures, however, indicate a less depleted mantle (LDM) component, suggesting that the behaviour of light and heavy noble gases are decoupled. Despite the presence of large amount of in situ component, progressive vacuum crushing technique for gas extraction has helped in the further decomposition of the trapped component from South Indian carbonatites into those of LDM and an overwhelming contribution from an enriched lithospheric mantle. The Indian carbonatites studied by us appear to have been generated during the waning stages of plume magmatism leading to considerable depleted and lithospheric mantle inputs as the uprising deep magma induces their melting and subsequent entrainment.

(S. Basu and S.V.S. Murty)

Impactor Signatures in Glasses from Lonar Crater

We have analysed noble gases from two types of Lonar impact glasses to elucidate their formation histories. In one of the tektite-like samples correlated excesses due to cosmogenic ^{21}Ne, primordial ^{36}Ar and radiogenic ^{129}Xe have been found, which are distinct signatures of a meteorite. This can be understood in terms of physical trapping of a small amount of the bolide (that made the crater) in the impact glass. This is the first report of the identification of impactor noble gas signatures in an impact glass.

(S. Managave and S.V.S. Murty)

Age of the Sylhet Traps, Eastern India

We have successfully dated the age of emplacement of the Sylhet Traps, eastern India by ^{40}Ar-^{39}Ar method. Our results provide concordant ages for two samples, vertically separated by ~200 m, from a tholeiite lava flow sequence. The ages are indistinguishable at 2σ confidence level indicating very rapid emplacement of these lavas. The weighted mean of the plateau ages associated with least errors, 116.0±3.5 Ma, most likely represents the age of eruption. Clearly, the Sylhet Traps are contemporaneous with the Kerguelen plume generated Rajmahal and Bengal Traps. Our results in conjunction with the existing age data in the Rajmahal-Bengal-Sylhet igneous province suggest that the latter experienced widespread and rapid emplacement of flood basalts at ~118 ± 2 Ma. Such a large-scale volcanism would have required a direct involvement of the Kerguelen plume, suggesting that the Kerguelen hotspot was located close to the eastern Indian margin during its initiation. This work has been done in collaboration with Dr. K. Pande, IIT, Mumbai.

(J.S. Ray)

Radiocarbon Dating of Marine Sediments

Radiocarbon dating is a very useful tool to determine the rates of sediment accumulation in the marine environment, particularly to quantify detrital flux from land, to trace sediment pathways and to infer paleomonsoon and palaeoclimate of the adjacent land. With this in view, radiocarbon measurements in sixteen sub-samples from two sediment cores viz. SK-181-4 and SK-181-5, off the Kerala coast, the south-western coast of India, was taken up. These cores have meagre carbonate content; therefore bulk organic fraction was subjected to radiocarbon dating. Ages obtained for sediments at 50 cm depth are 11.5 kyr BP and 13.5 kyr BP and for sediments at the bottom of the core, they are 31.5 kyr BP (at ~380 cm core depth) and 30.8 kyr BP (~at 470 cm), respectively for SK-181-4 and SK-181-5. These ages suggest that the average sediment accumulation rate is marginally lower for SK-181-4 (0.16mm/yr, 180 m water depth) than SK-181-5 (0.24mm/yr, 255m water depth). This trend could be due to differences in the load-carrying capacity of the rivers and lithology of the hinterland. Accumulation rates also vary along the core lengths and could be attributed to the past monsoonal fluctuations.

(M. G. Yadava and K. Pandarinath)

Multi-Tracer Groundwater Ages in North Gujarat Cambay Region

The groundwater radiocarbon ages in the North Gujarat Cambay (NGC) region were found to range from modern (in the recharge area) to >35 ka (in the discharge area). Therefore ^{4}He and $^{4}He/^{222}Rn$ dating methods were also employed, particularly where radiocarbon ages beyond dating limit (~35 ka) were obtained. The iso-distribution maps of groundwater ages by the three employed methods (^{14}C, ^{4}He, $^{4}He/^{222}Rn$) show progressive increase in the general flow direction of groundwater, i.e., towards southwestward. Estimate of both ^{4}He and $^{4}He/^{222}Rn$ ages critically depended on appropriate value of helium release factor. Although the range of values for helium release factors are available in literature, a novel approach of matching the ^{4}He and $^{4}He/^{222}Rn$ age progression gradients with that of ^{14}C age gradient, which is more reliable, was adopted to arrive at the most appropriate value of helium release factor. It is seen that for a helium release factor of 0.4, the age progression gradients by the three methods match. Over long time scale (~100 ka), the lower value of helium release compared to conventionally accepted value of 1, is probably consistent with several known instances of anomalous ^{4}He release during rock dilation and fracturing in association with earthquakes and enhanced release of geologically stored radiogenic helium in relatively young fine grained sediments derived from old rocks.

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

Dating Complex Environments (Tsunamis) by OSL

The time dependence of luminescence emission from Quartz on optical stimulation (OSL) can be modelled by the sum of exponentials, each corresponding to a characteristic trap with a specific trap depth and photo-ionization cross section. The intensity of an OSL decay curve can be expressed as

$$I_{osl}(t)=\sum_{i=1}^{n} I_{oi}\, e^{-\lambda_i t}$$

where I_{oi}'s are the intensities and λ_i's are the corresponding decay constants. These components from OSL decay curve were isolated using Levenberg-Marquardt and Dog-Leg algorithm and, this was tested using standard techniques such as autocorrelation of residual, F-test, minimum of chi-square etc. This was then extended towards a routine use of components for dating of samples. This provided us a way to date more complex sediments, where perhaps the most rapidly decaying component was only bleached. The method was tested on the samples of tsunami event of 2004. Analysis of eight samples from the Pichavaram – Chennai transect, indicated that these samples were indeed bleached and had a signal ~0.5± 0.5Gy indicating near total bleaching. Given the catastrophic nature of the event, it appears that only the sands from the inter-tidal region were reworked by the event.

The component specific analysis also permitted isolation of the optical signal from feldspars on the basis of the fact that components of quartz and feldspar OSL decay signals are different. We demonstrated that the fast component of Quartz OSL can be isolated. This work has been done in collaboration with H. Achyuthan, Anna University, Chennai on Tsunami sands.

(M.K. Murari and A.K. Singhvi)

Assessment of Beta Dose Heterogeneity on Single Grain Luminescence Dating

We demonstrated that microscopic fluctuations exist in the spatial distribution of feldspar containing ^{40}K β emitters (termed hotspots), in the sediment matrix. We then modelled and quantified these fluctuations and their effect on the distribution of doses in quartz. The approach involved, 1) computation of the doses to a quartz grain from a configuration of the hotspots within a sphere of maximum beta range and, 2) deduction of dose distribution by averaging over all possible configurations. A positively skewed dose distribution function was seen. The magnitude of its effect on the palaeodose distribution in quartz was estimated as a function of K concentration (lower the potassium, higher is the hotspot heterogeneity and broader is the relative width of the palaeodose distribution) and the results suggest that even

with low potassium content, while the probability of grains receiving zero doses is negligibly small there is a large distribution of doses. We suggested a minimum dose concept through a percentile analysis of the distribution function, viz., as the lowest doses received by a small fraction of the grains (say less than 5%). The results therefore suggest a paradigm shift to the paleodose evaluation procedures using single grains and we anticipate it to find wide usage. This work has been done in collaboration with Y.S. Mayya.

(P. Morthekai, M.K. Murari and A.K. Singhvi)

Solar Control of the Southwest Monsoon (SWM) on Centennial Time Scales

A sediment core from the south-eastern Arabian Sea, a region significantly affected by monsoon runoff, has been analysed to test the role of solar forcing on the Indian South West Monsoon strength during the Holocene (the last 10000 years). This core was dated by radiocarbon using the Accelerator Mass Spectrometry facility at Arizona, in collaboration with scientists from the University of Arizona. We analyzed stable oxygen isotopic composition ($\delta^{18}O$) of three species of planktonic foraminifera (Gs. ruber, Gs. sacculifer and Gr. menardii) with high time-resolution (~ 50 yr) in the core, which helped us to document the past variations in the monsoon precipitation. Spectral analysis and visual matching of the high-resolution isotopic data from this region, best suited to study the monsoon precipitation, with Total Solar Irradiance (TSI) reconstruction indicates a possible solar control over the SWM on centennial time scales. Variations in the TSI (~0.2%) seem to be too small to perturb the SW monsoon unless assisted by some internal amplification mechanism with positive feedbacks. Although several suggestions, such as, heating of stratosphere due to increased absorption of solar UV and reduction of cloud condensation nuclides due to decrease in flux of galactic cosmic rays, during increased solar activity period, have been put forward, the exact linking mechanism is yet to be elucidated. This work has been done in collaboration with A J T Jull and G S Burr.

(R. Ramesh, B. L. K. Somayajulu and M. Tiwari)

Estimates of Atmospheric Carbon Dioxide during the Late Paleozoic and Mesozoic

The fluvial deposits of Motur (middle Permian), Denwa (late Triassic), Tiki (early Triassic), Bagra (middle Jurassic), and Lameta (late Cretaceous) formations of the Gondwana supergroup in central India contain a number of calcic paleosols. All of these paleosols are characterized by pedogenic carbonates occurring as rhizocretions and globules. Soil carbonates from several horizons of these formations were analyzed for oxygen and carbon isotopic ratios. Oxygen isotopic ratio is used to infer about the environment of precipitation and paleotemperature. The carbon isotopic composition of these carbonates and the coexisting soil organic matters provided indirect means to determine the isotopic composition and the partial pressure of atmospheric CO_2. The estimate shows that the concentration of CO_2 was low (~710 ppmV) during the early Permian (275 ± 15 My) followed by continuous rise during the middle Triassic (~1215 ppmV at 235 ± 5 My), late Triassic (~1170 ppmV at 225 ± 15 My), and the Jurassic (~2240 ppmV at 175 ± 30 My). It is seen that the CO_2 level increased by a factor of 8 from the Permian to the Jurassic and declined again during the Cretaceous. The late Cretaceous P_{CO2} estimate is approximately 1480 ppmV, higher than the predicted concentration (~1000 ppmV). Degassing of Earth's interior caused by the rapid breaking up of the Gondwana landmass during the Triassic and Jurassic periods could have caused the rapid evolution of CO_2; subsequent biotic proliferation in the Cretaceous probably lead to its slight decline.

(Prosenjit Ghosh and S.K. Bhattacharya)

Mio -Pliocene Monsoonal Record from Himalayan Foreland Basin and its Relation to the Vegetational Change

The carbon and oxygen isotope ratios of soil carbonate nodules and carbon isotope ratio of associated organic matter were measured from three Indian Siwalik successions to reconstruct vegetational history and change in contemporaneous precipitation. $\delta^{13}C$ of soil carbonate shows that from 10.5 Ma to 6 Ma the vegeta-

tion was C_3 type and C_4 grass appeared around ~ 6 Ma . The $\delta^{18}O$ variation of soil carbonate suggests that the monsoon system intensified with one probable peak at around 10.5 Ma and a clear onset at 6 Ma with peak at 5.5 Ma; after 5.5 Ma monsoon strength decreased and attained the modern day condition with minor fluctuations which is supported by marine proxy of upwelling in the Arabian Sea and sedimentary morphology in Siwalik. The covariation between $\delta^{18}O$ and $d^{13}C$ data suggests that a change in precipitation pattern was partly responsible for expansion of C_4 grass. It is seen that in a mixed C_3-C_4 environment estimation of abundance of C_3 and C_4 plants using soil carbonate in one case and residual soil organic matter in another may differ. This can be explained by assuming that the plant respired CO_2 is the main contributor of carbon in soil carbonate and may have different isotopic composition from that of the residual organic matter in the soil. In addition, the abundance estimate of C_3-C_4 plants also shows variation with time, probably caused by change in growing season condition through time.

(Prasanta Sanyal and S.K. Bhattacharya)

Thar : Paleohydrology of Saline Playas

Paleohydrological changes in Phulera (eastern margin, 500mm/a) and Pokharan (western arid core, rainfall ~ 200mm/a) were reconstructed using lithostratigraphy, mineralogy, geochemistry, stable isotopes and optical dating. In Pokharan playa sediments, high energy fluvial environment was inferred during ~ < 5.2 ka – 4 ka followed by fluctuating brackish and fresh water condition during 4 – 2.5 ka and hyper saline condition during 2.5 -1.3 ka. In Phulera basin, hyper saline lacustrine condition was infrerred during < 3.1 ka to >1.4 ka indicating weakening of monsoon. Further, during this period, increased abundance of gypsum ($CaSO_4.2H_2O$) in Pokharan and proto-dolomite [Ca (Mg, Fe)$_{1-x}$ $(CO_3)_{2-x}$] in Phulera, suggests that evaporation was relatively higher in the west compared to east attributable to reduced precipitation over the Indian sub continent. Both the playa became progressively less saline after 1.4 ka, suggesting improved monsoon probably corresponding to the medieval warming. This work has been done in collaboration with W. Smykatzkloss. University of Karlsruhe, Germany.

(P.D. Roy, Y.C. Nagar , N. Juyal and A.K. Singhvi)

Thar : Gypsum -Chronology, Formation Pathways and Paleoenvironment

The main aim of this study was to understand and resolve various aspects of dating and characterization of gypsum. In Thar Desert, gypsum occurs extensively in interdunal depression, playas and palaeo-drainages. Powder X-ray diffraction (XRD), Fourier Transform Infrared spectrometry (FT-IR) Differential Thermal Analysis (DTA) were used for its characterization and Electron spin resonance (ESR) for its direct dating. In addition, optical dating of sediment above and below the gypsum horizons provided indirect age estimates. Mineralogy of the gypsum indicated its association with calcite ($CaCO_3$) and Hannabachite ($CaSO_3$ 0.5 H_2O). ESR analysis indicated significant amount of Mn^{2+} (**Fig. 7.3**), suggesting anoxic conditions during Gypsum precipitation. The presence of sulphur as sulphite suggested redox cycles that resulted in the coexistence of sulphite and sulphate phases. Microbial reduction of sulphate to H_2S and/or elemental sulphur and their subsequent oxidation to SO_2, and its reaction with $CaCO_3$, can form gypsum along with reaction intermediate Hannabachite $CaSO_3$ 0.5H_2O

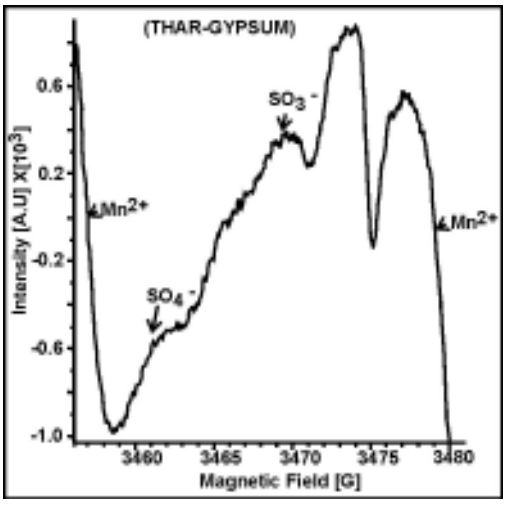


Fig. 7.3 A typical Electron Spin resonance spectrum of Gypsum.

and some un-reacted calcite. This work has been done in collaboration with S.K.Wadhawan, GSI, Gandhinagar K.P.N. Mishra, B. Bhushan, M.N. Deo, BARC, Mumbai

(Y.C. Nagar, N. Juyal, M.D. Sastry and A.K. Singhvi)

Sediment Fluxes, Erosion and Human Impact in Himalaya

River Alaknanda suffered an unprecedented flood and sediment transport during 1970, attributed to deforestation. To determine the source of these sediments, we used optical dating technique along with the isotopic tracer, εNd(0).

Different lithological units viz. the Tethyan sedimentary sequence (TSS), Higher Crystalline Himalayan sequence (HCH), Lesser Himalayan sequence (LH) and Lower Siwalik sequence (LS) have characteristic values of εNd(0). The present day sediment flux from TSS, HCH, LH, LS was quantified by successively using a linear two-end- member mixing model involving the values at the entrance and exit of a lithozone. The results indicated that at Rishikesh, about 54% of the modern river sediment is from the higher central Himalaya and the remainder from the Lesser Himalaya. An optically dated, fluvial sequence of the Alaknanda river at Srinagar provided the time-specific history of sediment sources from 6300 years to 230 years. At 6300 years and 2700 years the sediment was largely from higher central Himalaya; at 800 years the sediment was contributed equally from the Lower and the Higher Central Himalaya and the 400 year and 230 year flood deposits came mostly from the higher central Himalaya. The 1970 deposit came from the lesser Himalaya whereas the modern sediment comes from the HCH.

These results suggest that during the past two centuries of deforestation, the Lower Himalaya, where most trees were removed, has contributed on average only ~10% more sediment than in the previous 600 years. Importantly about 800 years ago, the inner LH provided nearly half of the sediment implying that geodynamic processes can lead to enhanced contribution from the LH even without deforestation. This implies that the majority of the sediment flux during the past 6000 years was generated by natural process and sourced from the topographically high HCH, however the 1970's flood has generated additional minor inputs from the deforested LH watersheds.

(N. Juwal, M. Jaiswal, A. K. Singhvi and M. M. Sarin)

Water-Soluble Organic Compounds in Atmospheric Aerosols

Aerosols act as a transport path for water-soluble organic compounds (WSOC) to the atmosphere. WSOC can transform the surface layer of aerosols from hydrophobic to hydrophilic and influence their chemical and optical properties and thus the radiation balance of the atmosphere. Concentrations of water-soluble inorganic ions, organic compounds and total organic carbon were determined in bulk-aerosols collected on daily basis during winter (1-31 December 2004) from an urban-site (Hisar) in North India. The winds were generally north-easterly with speed generally less than 1 ms^{-1}. The concentration of total organic carbon (OC) varied from 13.6 to 55.6 mg m^{-3}; accounting for 7.7 to 22% of aerosol mass loading. On average, nearly 36% of OC was water-soluble (**Fig. 7.4**). The mass ratio of WSOC to soluble-inorganic ions varied from 0.22 to 0.61; suggesting that substantial quantities of aerosols are derived from dust emissions. Both WSOC and OC exhibit significant positive correlation with potassium (r^2 = 0.73, n = 31); suggesting that their abundances are dominated by local biogenic source (biomass burning). In contrast, sulphate (SO^{2-}_4

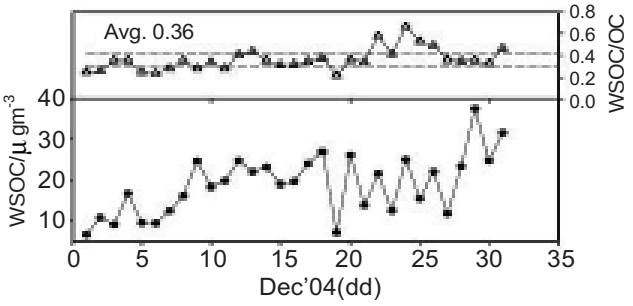


Fig. 7.4 A typical daily variation in aerosol abundance of WSOC & mass ratio of WSOC & total organic carbon (OC) over an urban site (Hisar) in North India.

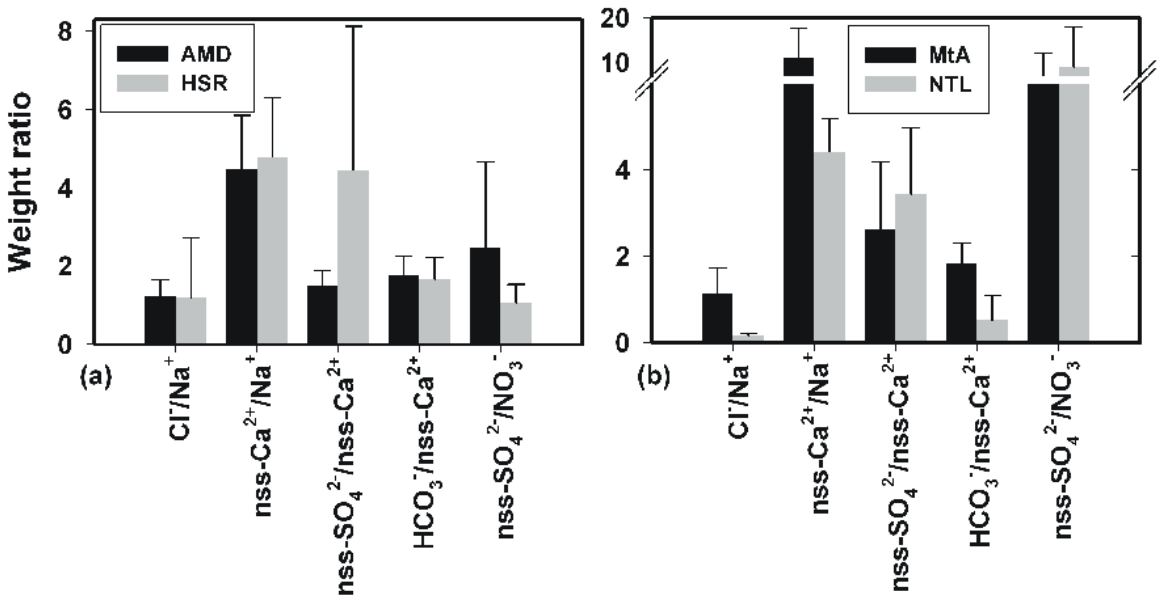


Fig. 7.5 Average ionic ratios (bar length) and standard deviation (error bars) for major ionic species measured in aerosols, (a) Over Ahmedabad (AMD) and Hisar (HSR), and (b) Mt Abu (MtA) and Nainital (NTL).

range: 3.9-25.5 mg m^{-3}) exhibited only weak covariance with WSOC and OC, indicating that contribution of organic constituents by anthropogenic aerosols is relatively insignificant.

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

Chemical Characteristics of Atmospheric Aerosols at High and Low Altitude Sites

Chemical characteristics of winter aerosols have been studied from four sites: Ahmedabad (23.0°N, 72.6°E, 49 m asl), Mt Abu (24.6°N, 72.7°E, 1680 m asl), Hisar (29.2°N, 75.7°E, 216m asl) and Nainital (29.4°N, 79.5°E, 1940 m asl). The two high altitude sites: Mt Abu and Nainital represent free tropospheric conditions during winter. The weight ratios of major ionic species, measured in water extracts of aerosols, are compared in **Figs. 7.5a** and **7.5b**. At low altitude sites (Ahmedabad and Hisar), Cl^-/Na^+, nss-Ca^{2+}/Na^+ and HCO_3^-/nss-Ca^{2+} ratios are comparable while nss-SO_4^{2-}/nss-Ca^{2+} and nss-SO_4^{2-}/NO_3^- are significantly different. These differences are attributable to relative dominance of anthropogenic emissions over Hisar. In contrast, major differences in Cl^-/Na^+, nss-Ca^{2+}/Na^+ and HCO_3^-/nss-Ca^{2+} ratios are observed over Mt Abu and Nainital; while nss-SO_4^{2-}/nss-Ca^{2+} and nss-SO_4^{2-}/NO_3^- are comparable. Such regional differences for high altitude sites arise due to semi-arid climate and high abundance of mineral dust at Mt Abu. Higher nss-SO_4^{2-}/NO_3^- ratios over high altitude sites than those over low altitude sites (**Figs. 7.5a** and **7.5b**) are attributed to the relative difference in the size distribution of SO_4^{2-} (fine mode) and NO_3^- (coarse mode) aerosols.

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

^{7}Be And ^{210}Pb Abundances over Low and High Altitude Sites in Western India

Simultaneous measurements of ^{7}Be ($t_{1/2}$ = 53.3 d, cosmogenic) and ^{210}Pb ($t_{1/2}$ = 22.3 y, produced from decay of ^{222}Rn) were made in ground-level air at Ahmedabad: (23.0°N, 72.6°E, 49 m asl) and Mt. Abu (24.6°N, 72.7°E, 1680 m asl) .On an average, ^{7}Be is relatively high (~20%) at Mt Abu than that over Ahmedabad because of their

altitude difference; the seasonal variability, however, is quite similar over both the sites. The concentrations of ^{7}Be and ^{210}Pb were lowest during rainy period (May-Aug); resulting from their removal by wet scavenging. The observed seasonal variability in ^{7}Be and ^{210}Pb activities is quite uniform over the sampling period of three years and can be explained in terms of vertical mixing of the atmosphere, residence times of aerosols and lateral transport of air masses. There is a significant correlation of nss-K^+ (r^2 = 0.69) and Pb (r^2 = 0.88) with ^{210}Pb in Mt. Abu aerosol samples, suggesting a common transport pattern for these species derived from anthropogenic and biogenic emissions. These observations have implications to the use of ^{210}Pb as a tracer of long-range transport of continental constituents to the open ocean; whereas the analysis of ^{7}Be data reflects its ability to act as a tracer of vertical mixing of tropospheric air.

(N. Rastogi and M. M. Sarin)

Chemical Characteristics of Atmospheric Aerosols at Manora Peak, Nainital

Time-series samples (n=20) of bulk-aerosols collected during December 2004 from Manora Peak, Nainital (1950 m asl, 29.4°N; 79.5°E) as a part of ISRO-GBP land campaign II, has been analyzed for their chemical composition indicating water-soluble inorganic constituents and organic compounds (WSOC). The prevailing meteorology at Manora Peak is north-westerly wind circulation, with low relative humidity (< 50%) and scanty rainfall. On an average, water-soluble components (8.5 $\mu g\ m^{-3}$) account for about 30% of total aerosol mass (Av. = 27 $\mu g\ m^{-3}$). Among cations, Ca^{2+} was the most abundant with Ca/Mg mass ratio of ~ 8 suggesting that chemical composition of aerosols is dominated by calcareous dust. Sulphate (range: 1 to 4.7 $\mu g\ m^{-3}$) was the major anion and exhibits significant positive correlation with NH_4^+ (r^2 = 0.94); indicating their dominant contribution from anthropogenic sources (e.g. $(NH_4)_2SO_4$). Relatively high abundance of WSOC (range : 1.4 to 6.0 $\mu g\ m^{-3}$), account for about 45% of water-soluble components and their significant (r^2 = 0.62) positive correlation with K^+ (range: 0.12 to 0.42 $\mu g\ m^{-3}$) provide evidence for their large-scale contribution from biomass burning. The chemical characterization of aerosols from high-altitude sites is, thus, essential for documenting the long-range atmospheric transport of sulphate and organic particles that play important role in climate and atmospheric chemistry. This work was done in collaboration with Dr. P. Hegde of Aryabhatta Research Institute of Observational Sciences, Nainital.

(M.M. Sarin and A.K. Sudheer)

Weathering and Erosion in River Basins of India

Studies on weathering of rocks are important as they are relevant to continental erosion and consumption of atmospheric CO_2, both of which address to Global change. Researches on this topic were continued, both in the Himalaya and Deccan basins. In the Himalaya the emphasis was more on spatial and temporal variations in physical erosion whereas in the Deccan it was on the relative mobility of elements during weathering and the impact of their contributions to elemental and isotopic fluxes of the Ganga.

Chemical weathering studies in the Deccan Traps, based on water chemistry, Sr isotopes in water and chemical composition of sediments have been completed. Present focus was on the geochemistry of Ba in the Deccan rivers and the role of Deccan in the long term $^{87}Sr/^{86}Sr$ variations in oceans. Concentration of Ba in water and sediments and its ratio relative to other alkaline earths suggest that chemical erosion of Deccan Basalt is incongruent with respect to alkaline earths, Ba being the least mobile. The sediment data on Ba supports this conclusion. Model calculations on the role of emplacement and weathering of Deccan on marine Sr isotope evolution around KTB and late Tertiary show that Deccan basalts can be an important contributor to the decline of $^{87}Sr/^{86}Sr$ during these periods.

Major Ion and Sr Isotope Composition of Source Waters of the Chambal River

The chemical and isotope studies of the Chambal river has been completed. The Chambal river Sr is less radiogenic (0.70923 to 0.71219) unlike the Himalayan Rivers, as the major sources of Sr to the Chambal are

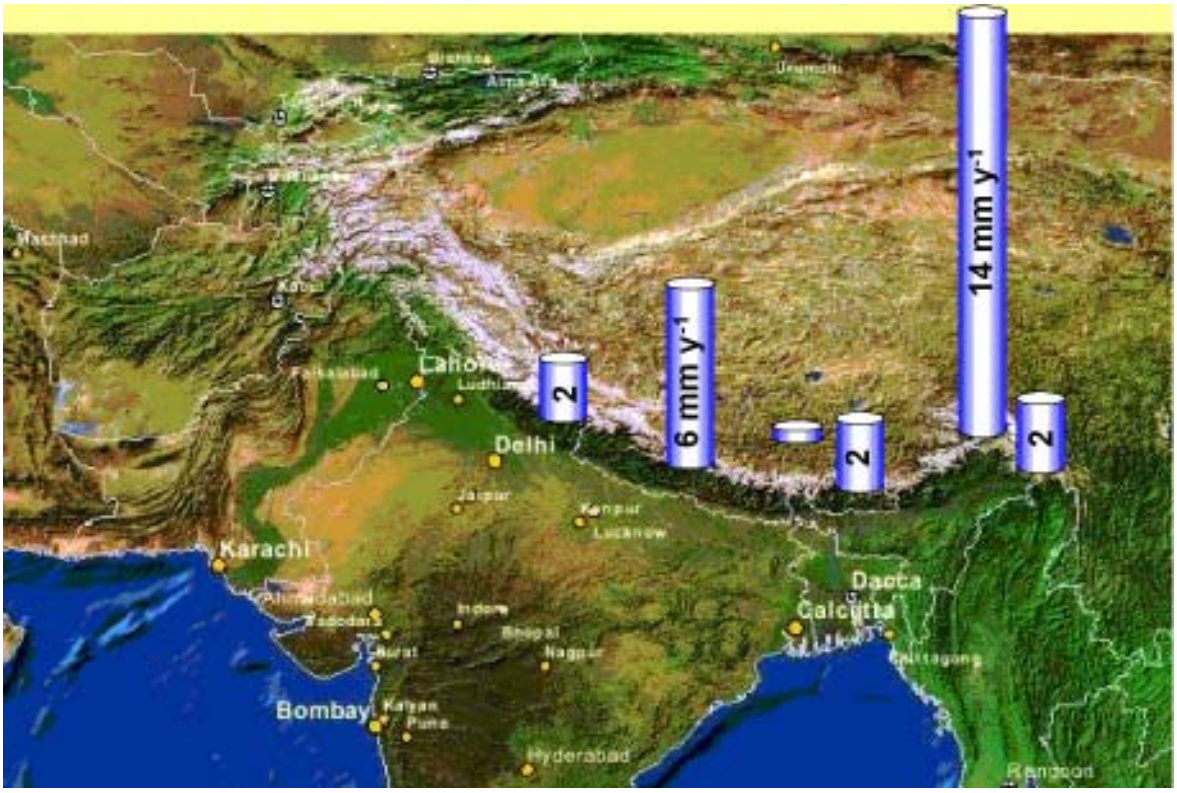


Fig. 7.6 Erosion Distribution over Central and Eastern Himalaya.

the Deccan Trap basalts and the Vindhyan sediments, which are low in $^{87}Sr/^{86}Sr$. The Sr isotope composition of the Chambal along with the available data for the Yamuna and the Ganga have been used to evaluate the impact of the weathering of the Deccan Trap basalts and the Vindhyan sediments on the Sr isotope budget of the Ganga. Mass balance calculation shows that, at Allahabad, the rivers from south contribute ~70% of the dissolved Sr to the Yamuna. Similar calculations for the Ganga demonstrate that the dissolved Sr of the Ganga, downstream Allahabad, is a result of 15, 25 and 60% contributions each from the Ganga upstream Allahabad, the headwaters of the Yamuna and the southern rivers characterized by the Chambal. This study supports that rivers draining the Deccan and the Vindhyan regions contribute significantly to the Sr budget of the Ganga and thereby dilute the radiogenic Sr isotopic composition of the Ganga.

(R. Rengarajan, M. M. Sarin and Sunil K. Singh)

Erosion Distribution over Central and Eastern Himalaya

The Sr and Nd isotope composition of sediments of the Ganga and the Brahmaputra rivers show that the Higher Himalaya is the primary source for these sediments and that the Himalaya is undergoing differential erosion. It is seen that basins with high relief such as the Gandak in the Ganga Basin and the Eastern Syntaxis of the Brahmaputra are eroding very rapidly at rates of ~ 6 and 14 mm/y respectively compared to other regions of these basins which have erosion rates of ~ 2 mm/y (**Fig. 7.6**). Such rapid erosion in these areas is causing rapid uplift resulting in the high peaks of the Namche Barwa, the Dhaulagiri and the Annapurna.

Chemical and Isotope Studies of Sediments of the Bay of Bengal

A detailed study of sediments of the Bay of Bengal has been initiated to trace their sources (i.e. Higher and

Lesser Himalaya vs Peninsular) and their relative contribution through space and time. Relative intensities of monsoon (NE/SW) and ocean currents are some of the factors which can influence the spatial and temporal variability in sediment contribution from these sources. These variabilities can be quantitatively determined from Sr and Nd isotope studies, as the end members have distinctly different values (Himalaya $^{87}Sr/^{86}Sr$ ~0.76, ϵ_{Nd}-18; Peninsular Rivers, $^{87}Sr/^{86}Sr$ ~0.72).

Towards this, a 12 m long piston core (collected by NIO scientists from 15°26.952' N 84°28.296' E) in the Bay of Bengal as a part of the BENFAN Programme, was sub-sampled at every 10 cm and brought to PRL for measurements of Sr, Nd concentrations and $^{87}Sr/^{86}Sr$ and ε_{Nd} by Thermal Ionisation Mass Spectrometry. Initial results show significant temporal variation in $^{87}Sr/^{86}Sr$ of silicate fraction of this core, from 0.72750 to 0.75515. Another sediment core collected at the 90° E Ridge display similar variation in $^{87}Sr/^{86}Sr$ in its silicate fraction, though with a much reduced range, 0.71123 to 0.71902. Further studies on chemical and mineralogical composition of these sediments, the isotope ratios in clay fraction and of source materials from the Himalaya and peninsular rivers are underway to elucidate the cause for the variation and the relation to climate and ocean circulation. Towards this, a set of samples from a sediment core from the Ganga basin has been analysed for their Sr and Nd isotopes, the results show significant temporal variation, from 0.73580 to 0.76510 and -16.6 to -14.4 respectively.

Dissolved Sr and its $^{87}Sr/^{86}Sr$ in the Ganga – Brahmaputra System

A programme to assess the temporal variations in dissolved Sr and its $^{87}Sr/^{86}Sr$ of the Brahmaputra (at Guwahati) and the Ganga (at Allahabad after confluence of the Yamuna) has been initiated. The idea is to obtain the magnitude of variability, its causes (silicate/carbonate weathering, mixing of rivers) and its influence on annual fluxes. Preliminary results show significant variations in both Sr and its $^{87}Sr/^{86}Sr$ over a ~10 month period at both the sites. In the Ganga, Sr content and $^{87}Sr/^{86}Sr$ vary from 1392 to 3412 nM and from 0.71696 to 0.72734 respectively and in the Brahmaputra they range from 622 to 1246 nM and 0.71602 to 0.71800. In the Ganga, Sr and $^{87}Sr/^{86}Sr$ exhibit opposite trend, a likely cause for this could be variation in mixing proportion of two components, one from the Himalaya and the other from Peninsular India (from Yamuna). In contrast, in the Brahmaputra, variation in Sr and its istope composition is a result of runoff and lithology. Interestingly, one of the monsoon samples of the Bramhaputra has high Sr content, resulting from flash flooding in its Tibetan sub-basin.

(A. Das, S.K. Singh, Santosh K. Rai, S. Krishnaswami, R. Bhushan and Gyana R. Tripathy)

New Production in the Southern Ocean

The southern Ocean is unique in many ways. It is rich in nutrients such as nitrate and poor in Chlorophyll, the so called HNLC (High Nutrient Low Chlorophyll) region. PRL scientists participated in the second expedition to the Southern Ocean and Antarctica organised by NCAOR, Goa and conducted experiments to measure the new and total production in the Southern Ocean and also in the coastal waters off the Antarctic continent using ^{15}N as tracer . In addition, the effect of iron on the productivity was tested by adding iron to sea water in two different sets of ex-situ experiments. All other oceanographic and atmospheric parameters, such as air and sea surface temperatures, nutrients, and chlorophyll, were also measured concurrently, in collaboration with scientists from NCAOR, Goa. This study will yield a comprehensive data to characterize the Southern Ocean biogeochemistry.

(Satya Prakash, R. Ramesh and R. Srivastava)

Records of Cosmogenic Radionuclides, ^{10}Be, ^{26}Al and ^{36}Cl in Corals: First Studies on Coral Erosion Rates and Potential of Dating Very Old Corals

We present results of measurements of cosmogenic ^{10}Be, ^{26}Al and ^{36}Cl, and the indigenous (intrinsic) concentrations of the stable elements, Be, Al and Cl in 120 - 200 kyr old corals from Barbados and Puerto Rico. The concentration levels of these radionuclides in the corals lie in the range 104 to 108 atoms/g. A com-

parison of the measured nuclide concentrations with those expected to be produced in the corals by nuclear interactions of energetic cosmic radiation shows that (i) the radionuclides, ^{26}Al and ^{36}Cl are derived from in-situ cosmic ray interactions in the corals after their formation, but that (ii) the radionuclide, ^{10}Be owes its provenance in the coralline lattice primarily due to incorporation of dissolved beryllium in sea-water in the lattice structure of the corals.

We discuss production rates and potential uses of cosmogenic radionuclides in corals, and the implications of the measurements reported here on the concentration of the cosmogenic radionuclides, ^{10}Be, ^{26}Al and ^{36}Cl. We show that the latter 2 radionuclides serve as gauges of coral terrace erosion rates, whereas the cosmogenic ^{10}Be is suitable for determining the ages of old corals, of ages exceeding a few million years, up to ~ 10 my. The erosion rates of the corals range from 0.7 to 5 x 10^{-3} cm/year, corresponding to an appreciable surface loss after aerial exposure: 1-3 m since the last interglacial and ~ 8 m since the penultimate interglacial.

(Devendra Lal, B. L.K. Somayajulu and others)

Design and Development of the HEX payload

The High Energy X - γ ray (HEX) spectrometer to be flown on Chandrayaan-1 mission scheduled for launch in early 2008 is intended for the study of low energy (30-270 keV) natural γ rays emanated from the lunar surface, due to radioactive decay of ^{238}U and ^{232}Th, using pixilated Cadmium Zinc Telluride (CZT) detector arrays. The geometric detector area of 144 cm^2 is realized by cascading 9 CZT arrays, each 4 cm x 4 cm (0.5 cm thickness) composed of 256 pixels. CZT detector array manufactured by M/S Orbotech, Israel, will be used. Signal generated by energetic photon incident on any of 2304 individual pixels are read out using a chain of XAIM 3.3 ASICs developed by Ideas, Norway, that allows identification of the triggered pixel and energy of the incident photon. The ASIC gives current output whose magnitude is proportional to the energy of the incident photon. The Front-End Electronics (FEE) for the HEX payload designed and developed by PRL (PLANEX) handles the analog ASIC outputs for energy, trigger and pixel address information. Precision I/V converter, peak detector and fast speed signal processing circuits have been designed for Pulse height analyzer and for address information. Energy information is digitized by 10-bit ADC and sent to processing electronics for transmission of the data.

Front End Electronics (FEE) for HEX payload

Various circuits of FEE for the HEX payload have been designed and successfully interfaced with the CZT detector. A schematic diagram of the front-end electronics system is shown in **Fig. 8.1**. Evaluation of different signal parameters with the interfaced circuits is being carried out. Low power DC-DC converter to generate high Voltage supply (-600V) has been designed for the CZT detector bias.

Detector board design for configuring nine CZT array detectors for the HEX is being worked out based on both thermal and electrical consideration. Layout design for placing the various electronic components is in the final stage. Mechanical design of the HEX detector package is nearing completion. The detector and front-end electronics (FEE) boxes will be integrated tray type package. The tray wise PCB layouts of different circuits are in progress. HV design has been finalized and its layout is in progress.

The spectra of energetic photons from specific sources observed using the in-house built FEE are shown in **Fig. 8.2**. The spectrum observed by activating one pixel using ^{152}Eu (40 keV and 122 keV) and ^{133}Ba (81 keV) source yielded energy resolution (FWHM) at room temperature of ~15% at 40 keV, ~10% at 81 keV and ~6% at 122 keV. Similarly we have also observed spectra for ^{57}Co source (122 keV) and the FWHM value is ~6% at 122 keV. The linearity in energy response (ADC channel number) has also been checked in the energy region 40-250 keV.

The characteristics of Orbotech CZT modules including its performance at low temperature, long-term behaviour etc. have been initiated.

Ground Checkout System for the FEE

A Ground Checkout System for the FEE of the HEX payload has been developed. It is a Pentium IV PC-based system that functionally checks the FEE hardware and the CZT detector array together. The FEE is connected to the PC through a Dynalog PCI 1751 card with 48 bit digital (TTL) I/O lines. The checkout software has been written in Microsoft Visual (C++ 6.0), which is a subset of Visual Studio.

The Ground Checkout System developed in PRL carries out 3 important operations to facilitate the testing of the detector board and the associated FEE. These are: (i) loading the ASICs with a required bit pattern; (ii) acquiring X-ray events incident on the detector (pixel, energy); and (iii) plotting of the energy spectrum. A sample spectrum acquired for a single selected pixel is shown in **Fig. 8.3**.

Effect of Solar Modulation on Lunar Gamma Ray Continuum Fluxes using GEANT4

The High Energy X- γ ray (HEX) experiment to be flown in the Chandrayaan-1 mission is designed to study the emission of low energy (30-270 keV) gamma ray emission from the lunar surface, and will represent the first attempt to study low energy γ ray emission from a plan-

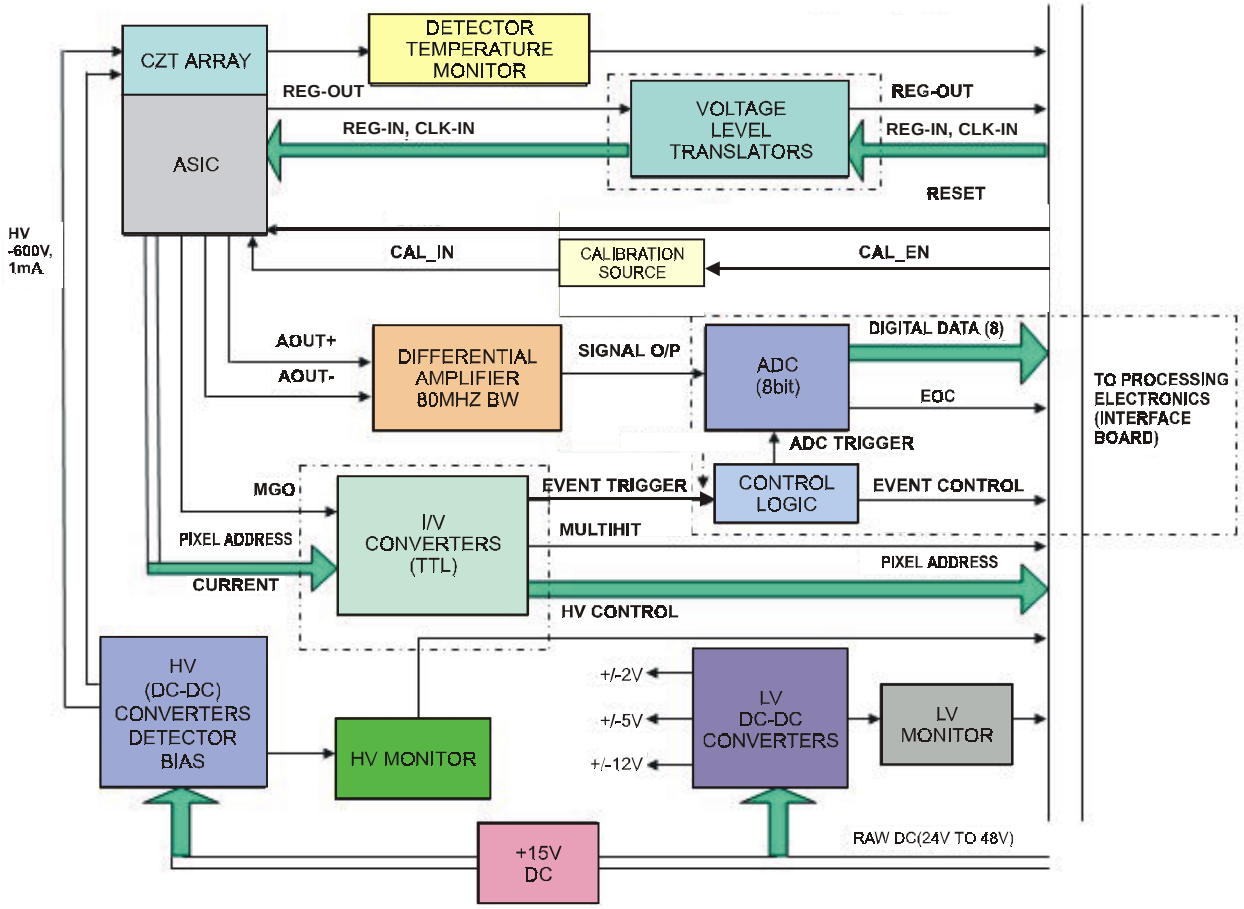


Fig. 8.1 Schematic diagram of front-end electronics for HEX payload.

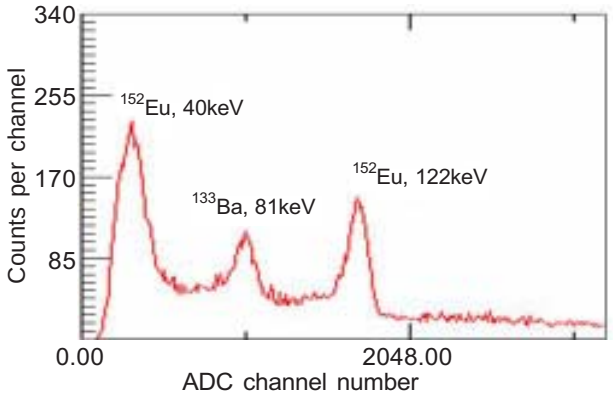


Fig. 8.2 Spectra recorded by one CZT pixel and PRL FEE using the gamma sources ^{152}Eu and ^{133}Ba.

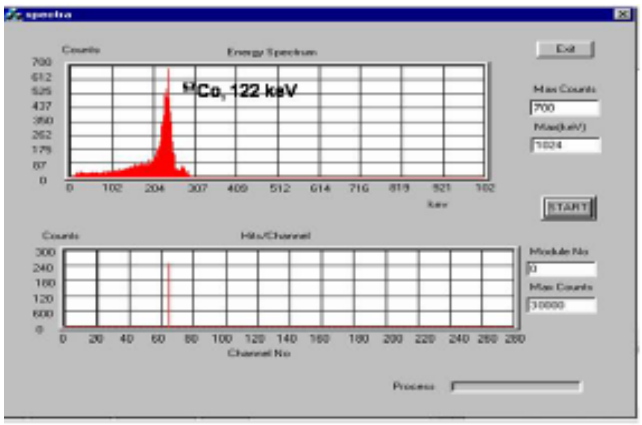


Fig. 8.3 Spectra recorded by a CZT pixel with PRL FEE and ground checkout system using the gamma source ^{57}Co.

etary surface. For estimating the lunar gamma continuum background expected from the lunar surface, we use the Geometry and Tracking (GEANT) code library to simulate electromagnetic and hadronic processes occurring on the Moon. The moon is simulated as a cylinder with a density of 1.6 g cm^{-3}, and an average atomic number of 13. The upper surface of the cylinder represents the lunar surface. We have previously estimated the lunar gamma ray continuum flux for different lunar compositions. However, the lunar gamma continuum is also dependent on solar activity. We have now estimated the lunar gamma ray continuum spectra for different solar activities for ferroan anorthosite (FAN) composition. The solar modulation parameters used were M = 600 (average), 900 (active) and 300 MeV (quiescent). The results obtained show that the lunar gamma ray continuum flux decreases from ~0.004 to ~0.0028 photons cm^{-2} sec^{-1} keV^{-1} from quiet to active solar periods.

Studies of Reflectance Spectra of Lunar Crater Populations

Reflectance spectra of lunar crater surfaces can be used to decipher the variation in mineralogical composition with depth on moon. This variation is a consequence of the global magma ocean as envisaged in the magma ocean hypothesis. To this end, multi-spectral reflectance data from the Clementine mission was analysed for four lunar far side craters to determine the most abundant mineral occurring at a particular depth. These craters had diameters between 50-150 km and have excavated material from a depth of ~5-15 km. Initial results suggest differences in mineralogical composition for craters of similar diameter indicating non-uniform crustal composition at similar depths in the lunar interior. In a related study, minerological and elemental (Fe, Ti) compositions were inferred from multispectral Clementine data for central uplift of the Tycho (85 km) and Copernicus (93 km) craters. The optical maturity parameter (OMAT) values were estimated for different units of the craters (crater floor, crater walls, ejecta and central uplift), and were found to be consistent with the known age of the craters, with the younger Tycho formed ~100 Ma ago, having a value of 0.26, while the ~800 Ma old crater Copernicus has an OMAT value of 0.19.

Thermoluminescence Studies of Chondrules from Dhajala Meteorite

Chondrules are millimeter sized spherical objects that comprise > 50% of the volume of chondritic meteorites. Their textural and petrographic characteristics suggest that they are formed by flash heating and cooling, although the exact mechanism is still not understood. The effect of parent body thermal metamorphism and possibly in the nebular environment prior to this, on the isotopic records in chondrules is still unclear. It has been shown previously that the thermoluminescence (TL) sensitivity of type 3.0 ordinary chondrites increases by a factor of 10^3 from type 3.0 (e.g. Semarkona meteorite) to type 3.8 (Dhajala meteorite), and that TL sensitivity is an indicator of the degree of thermal metamorphism experienced by unequilibriated ordinary chondrites. We have initiated thermoluminescence studies of chondrules from type 3.8 Dhajala meteorite to measure their TL sensitivity. Initial results show that all chondrules analyzed so far have lower TL sensitivities than the bulk meteorite and there is significant variation in TL sensitivity amongst individual chondrules. Chemical composition of some chondrules will be determined to understand whether the differences in the TL sensitivities amongst chondrules and between chondrules and the bulk chondrite sample can be explained on the basis of thermal history of chondrules.

(Y. B. Acharya, D. Banerjee, N. Bhandari, D. Dhingra, J. N. Goswami, V. G. Jardosh, S. Jogani, H. D. Mandliya, R. Mishra, H. L. Patel, S. Purohit, M. Shanmugham, N. Srivastava, D. V. Subhedar and S. Vadawale)

Computer Centre

The Computer Centre is equipped with IBM RS-6000/SP Computer having 16 processors and 32GB RAM to cater for high computing needs of scientists. It also has high-end graphics station, IBM RS-6000 Model 270 with 4 processors and has acquired 2 Dual Processor Xeon based servers providing additional computing power. These servers also provide 500GB disk space. All these computing machines are connected to our high-speed (100/1000 Mbps) local area network (LAN) to provide easy, fast and reliable access to more than 200 PC's and a 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. The Thaltej campus is connected to the main campus by a 2.4 GHz Microwave link that combines the LAN at both the campuses. Thus full connectivity has been provided to users all the time from anywhere to the Main Campus, Thaltej, USO, and Abu. Our Thaltej campus is connected via BSNL 2 Mbps MLLN for voice thus providing intercom telephone facility between the campuses. 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 centre also provides web enabled email service. Internet authorizations, monitoring and reporting functions have been added to have optimal usage of Internet bandwidth.

PRL SPACENET connectivity for Data and Intranet has been established. We have set up SPACENET email, web and DNS server. PRL members can use this facility, from a few selected machines, to interact with all the ISRO centres.

A video conferencing facility in PRL has been set up and is now fully operational at present. Video conferences can be conducted with ISRO centres (SPACENET) and other national and international institutions on IP and ISDN protocols.

Mathematical, numerical and visualization application software like IMSL, IDL, Mathematica, SigmaPlot, Lahey FORTARN 95, and 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 material 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 21,730 books, 31,405 bound volumes of journals, 768 audio visual (A-V) documents, 363 reports and 3404 reprints of PRL authors. It subscribes to 144 international and national journals. One hundred and eighteen journals can be accessed online. It is also subscribing to few e-books from Springer. All functions of the circulation desk have been automated using the LIBSYS software. 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 161 books in English, 80 books in Hindi and 76 CDs to its collection during the year. It has fulfilled 302 ILL requests from other libraries and received 82 documents on ILL from other libraries. About 1 lac photocopies were made from the in-house photocopying machine during this period. The library procured 6 articles from STN, which is a paid Documentary Delivery Service.

PRL library has a digital library which includes the PRL archive and its repository from 1995 onwards. The PRL publications and PRL doctoral theses have been digitised. Almost 1500 scientific papers, 60 theses and 25 technical reports have been made available over the LAN. PRL publications like Annual Report, Hari Om Award Lectures and others have been digitised and are included in the Digital Library. More than 1500 photographs have been archived in the digital library. PRL acquired a CD server through which the CD collections in the library

can be accessed from anywhere in the four campuses of PRL through LAN. In addition, it also has a server which houses the mirror backup of Libsys content and the Digital Library.

PRL is a member of the FORSA (Forum for Resource Sharing in Astronomy and Astrophysics) consortium to access the journals in electronic format. We have been subscribing to Nature online and Springer journals (online) through FORSA since last 3 years. This year, through FORSA Consortium, the library has subscribed to *Lecture Notes in Physics* and *Scientific American Online*.

The library staff also imparts training to the library trainees on all the aspects of library functioning and computer applications. Five trainees received training this year.

Workshop

PRL Workshop is a general-purpose workshop (mechanical) that provides extensive support to scientists and engineers. The Workshop has a 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 precise mechanical components and helps the scientists to establish various systems for different experimental set up.

The Workshop also carries out sheet and structural metal fabrication jobs. The high vacuum welding joints are also carried out by using TIG welding machine. The Workshop is equipped with one CNC Lathe Machine to carry out precise turning jobs. Various lens adaptor, optical components and mounts were fabricated at the workshop.

One of the major work carried out during the year is the fabrication of the mechanical systems and assembly of the payload for measuring electron density and nightglow emission in rocket-borne experiment. The mechanical system manufactured for the experiment are:

i. Front Looking Photometer Assembly (FLP) consisting of six photometers each having a different optical filter mounted along this rocket axis.

A Langmuir Probe and Photometer Assembly fabricated at workshop for measuring Electron Density and studying Nightglow Emissions for rocket borne payload, ABHA. The work of designing and modeling of Electronics Package Box has been completed by using software Mechanical Desk Top (MDT-6) and also fabricated at workshop.

ii. Side Looking Photometers to see this signal side ways. Each Photometer contains focusing lenses, optical filters and a photo multiplier tube mounted with the help of threaded ring.

iii. A LP sensor spherical in shape has been mounted along the centre line of Front Looking Photometer assembly.

iv. High voltage power supplies for the photo multipliers have been mounted in the milled boxes which also serve as mounting platform for the photometer assembly.

v. Electronics Package Box for Photometer and LP Electronics.

The precision mechanical components for photometer were fabricated on CNC Lathe machine. One photometer assembly consists of 10 parts which requires accurate dimensions and interchangeability. About 40 photometer assemblies (about 240 components) were fabricated.

Four payload units were fabricated and assembled in workshop. The necessary accessories were also made for the environmental testing of the payload.

A rigid Mild Steel structure was designed and fabricated for Dial-Telescope in dial lab. The Dial-Telescope has been installed on the structure and leveled perfectly with the floor and lens. The facility for the fine adjustment and leveling of telescope is provided with structure. The various adaptors, couplings and mounts were also designed and fabricated to mount telescope and PMT housing with structure.

Engineering Services

The Engineering Services Section renders all the technical services pertaining to 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 four campuses situated at Ahmedabad, Mt. Abu and 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. J. N. Goswami FNA, FASc, FNASc, FTWAS	Solar System Studies (Pre - Solar Processes)	Ph D PRL, Gujarat Univ. (1978)
Prof. G. S. Agarwal FNA, FASc, FNASc,FTWAS	Quantum Optics, Nonlinear Optics and Laser	Ph D Rochester Univ. (1969)
Prof. S. Krishnaswami FNA, FASc, FNASc, FTWAS	Aqueous Geochemistry and Nuclear Oceanography	Ph D TIFR, Bombay Univ. (1974)
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, FNASc	Isotope Geochemistry	Ph D PRL, Gujarat Univ. (1980)
Prof. P. Venkatakrishnan	Solar Physics	Ph D, Bangalore Univ. (1984)
Prof. S. D. Rindani	Particle Physics	Ph D IIT, Bombay (1976)
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)
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)

Name	Specialisation	Academic Qualification
Prof. A. Jayaraman FASc	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. T. Chandrasekhar	High Angular Resolution Studies, Late type stars, Solar Coronal Studies, Comets	Ph D PRL, Gujarat Univ. (1982)
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. 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)
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)

Name	Specialisation	Academic Qualification
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)
Dr. Santosh V. Vadawale	High Energy Astrophysics & X-ray Spectroscopy	Ph D, TIFR, Mumbai Univ. (2003)