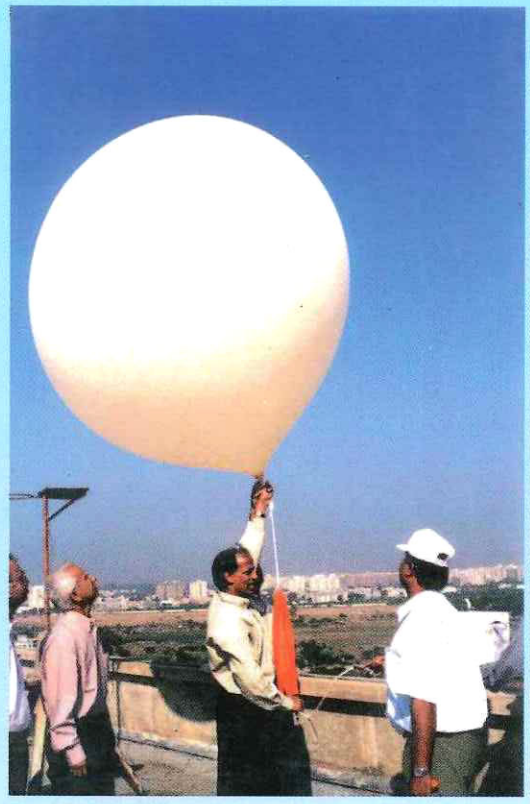
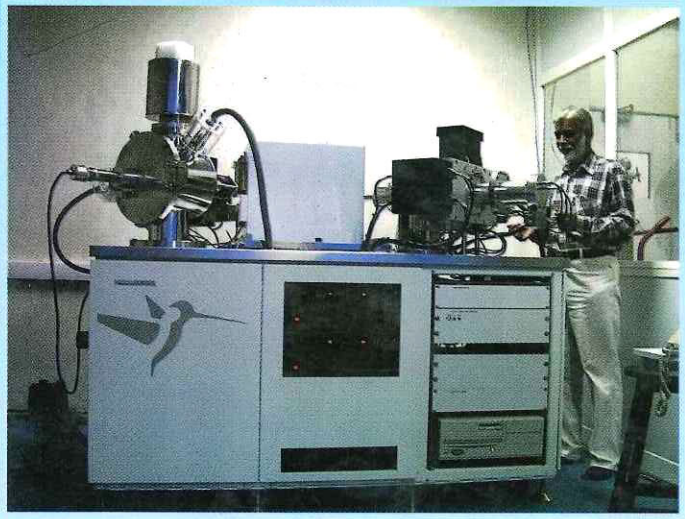
वार्षिक रिपोर्ट

Annual Report

2003-2004

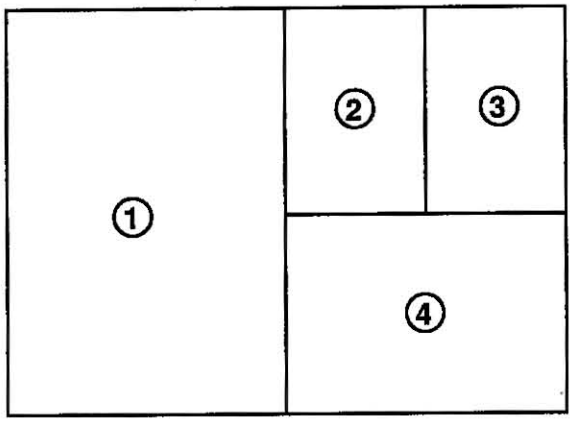


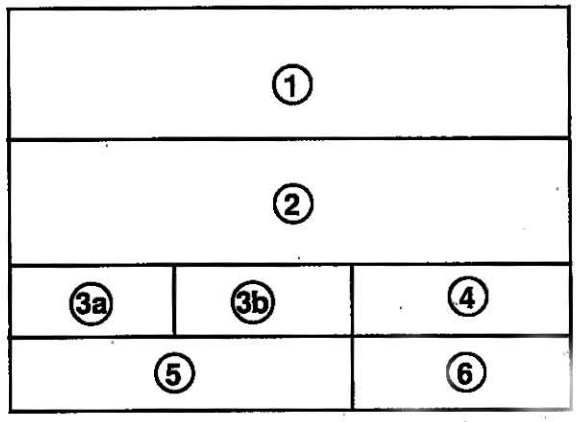


भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद

Physical Research Laboratory, Ahmedabad

वार्षिक रिपोर्ट
Annual Report
2003-2004





Title Cover :

1. *Balloon flights being conducted from PRL.*
2. *The chromospheric flare observed in NOAA0486 from Udaipur Solar Observatory on 28 October, 2003. Maximum phase of the 4B/X17 flare was observed around 11:10UT. Full disk white light, and Hα images show the three large active regions on this day of unusual sunspot activity.*
3. *An image of the light-echo around the nova V838 Mon in the infrared J band (1.25 microns) from the Mount Abu observations.*
4. *A state of the art Thermal Ionization Mass Spectrometer (TIMS), capable of measuring ratios of different isotopes very precisely (up to a precision of 5 parts per million).*

Inner Title Cover :

1. *Visit of parliamentary committee on Science & Technology, Environment and Forests.*
2. *Glimpses from the 73rd Annual Session of National Academy of Sciences.*

3a. *Dr. A. Jayraman receiving the PRL Award from Prof A.P. Mitra, FRS.*

3b. *Hari Om and PRL Award recipients with Prof. A.P. Mitra and Prof. G.S. Agarwal.*

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6. *Prof. V. Ramaswamy delivering the K.R. Ramanathan Professorship lecture.*

Inner Back Cover :

Glimpses of few events at PRL.

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Introduction

Physical Research Laboratory is a premier institute in the country with vibrant research programmes covering space and atmospheric sciences; planetary sciences, laser science, particle physics, atomic & nuclear physics.

One of the most important long-term programmes in astronomy and astrophysics, has been to monitor bright transient events such as Novae and Be phenomena. Novae are basically binary systems in which an evolving giant star transfers mass on to a compact white dwarf companion thereby creating on the latter's surface a runaway thermonuclear reaction. Our scientists have discovered two very rare novalike phenomena: one is that of a 'nova' that is deprived of hydrogen spectrum but high in helium and carbon lines and the other that behaved initially like a nova but showed later on evidence, in the form of molecular lines in emission/absorption, of a cold environment. The first of these two phenomena is evidently the discovery of a "helium nova" which remained hitherto as only a theoretical postulation. The second is also indeed a very rare phenomenon in that the novalike outburst does not possess any of the classical nova characteristic features. These cold objects, which are putative binaries, are now called 'quasi-nova'. Also the AlO molecule in these objects is a very rare moleculer to be observed in astrophysical sources.

Our scientists have been making radio observations on pulsars, giant radio galaxies as well as the Sun from the GMRT facility. The first successful solar imaging observation using the GMRT at 1060 MHz has led to the detailed understanding of a flare – Coronal Mass Ejection event that took place on 17 November 2001. This provided the first observational evidence in support of the break out model that the reconvection process initiating mass ejection begins from the top of the coronal loop as opposed to the root of the loop.The GMRT observations at 333 and 617 MHz of a giant quasar at a redshift of 1.005, revealed that this object is the largest single object observed beyond a redshift of 1(a size of 1.9 Mpc). The giant size is attributed to a lower pressure of the intergalactic medium than expected nearby giant radio galaxies.

The discovery of moving patterns of magnetic features within sunspot umbrae has been the most noteworthy finding this year. Although the physical origin for these motions is yet unknown, this motion seems to be pointing at a dynamical, as opposed to a static, state of the sunspot magnetic field.

As a part of the Indian Space Weather program, the Solar X-ray Spectrometer (SOXs) was launched onboard GSAT 2 on May 8, 2003. The payload was designed, developed and fabricated at PRL. The payload has been commissioned for regular observations since 26 June, 2003. A number of good flares has been observed. Data analysis is under progress.

The Submillimeter wave laboratory facility at PRL has been established. The design and construction of a heterodyne receiver system has been initiated. A step tunable optically pumped molecular laser Local Oscillator (LO) was installed successfully. A narrow band IF state-of-the-art Chirp Transform Spectrometer (CTS) has been fabricated.

Our PLANEX group has been entrusted the responsibility of developing the High-energy X-ray payload that will be flown in the Chandrayaan -1 mission in collaboration with ISRO Satellite Centre. Currently the scientists are concentrating on understanding the remote sensing data on planets, studies of characteristics and response functions of a new type of X-ray detector proposed for the Chandrayan - 1 mission.

The program to study the aerosol cloud interaction and their effect on atmospheric radiation budget and climate at different locations in India is in full swing, using the state-of-the-art Micro Pulse Lidar fitted inside a mobile laboratory. Regular observations at Ahmedabad and special field campaigns, such as in western Gujarat during December 2002 and ISRO-GBP land campaign from Ahmedabad to Hyderabad and back in February 2004 have been made. Several interesting results such as the variation in aerosol vertical profiles from polluted urban regions to relatively clean continental sites were obtained.

Measurements of non methane hydrocarbons (NMHC) have been made for the first time at Mount Abu and Ahmedabad. These data are being used to study transport of the pollutants. Similar measurements have been made during cruises over the Bay of Bengal. Higher levels of pollutants are found over this marine region compared to over the Arabian Sea.

In February 2004, PRL participated in a land campaign and made extensive measurements of ozone and related trace gases at selected rural sites between Ahmedabad and Hyderabad. Higher level of ozone (~ 70 ppbv) during day time has been observed at these rural sites. The ozone and CO analysers were also flown around Hyderabad at different heights on one of the aircrafts of NRSA during this campaign.

Another important experiment conducted also in February 2004 is the multiple ionization cross-section measurements of Argon using INDUS-1 synchrotron at CAT, Indore. Charge states as high as Ar^{+4} were observed.

The Thermal Ionization Mass Spectrometer (TIMS – IsoProbe-T) has been successfully installed. Several runs of Sr and Nd standards show that the machine has internal precision of about 0.0001% for Sr and 0.0006% for Nd in static mode and 0.0006% and 0.0004% in dynamic mode. Sr isotopic composition is being measured in samples from the Himalayan rivers, evaporites and carbonates to assess the role of evaporites and the precipitation of Ca in controlling the Sr budget of these rivers.

A new gas chromatograph for the measurement of CFCs in ground water has been set up and calibration experiments using gas standards has been completed.

A summary of scientific achievements is given on page 5. A total of *one hundred and fifty five* papers have been published in high impact journals, of which *one hundred and thirty* were in international journals. During the year, our scientists participated actively in national and international conferences with large number of significant presentations, out of which *one hundred and three* were invited talks. At present, PRL has *forty six* research scholars and seven post-doctoral fellows besides other visitors working in various disciplines. *Five* Ph.D. theses were submitted. The topics covered were High Angular Resolution Studies of Late type Stars by Lunar Occultations in the Near Infrared; Evolution of Magnetic Field of the Solar Atmosphere; Radium Isotopes and Rare Earth Elements in Indian Rivers and the Bay of Bengal; Nitrogen and Noble Gases in Carbonatites of India and Studies in Coherent Control of Optical Processes.

Some of our scientists have received prestigious awards and honours such as the *Vice President, Indian National Science Academy*, *Fellow of Geochemical Society-European Association of Geochemistry; Young Scientist Awards*; *Fellowship of the Indian National Science Academy etc.*.

A **Parliamentary Committee on Science & Technology, Environment & Forests** comprising of twenty one MPs, both from Rajya Sabha and Lok Sabha, visited PRL on September 25, 2003 as part of the on-the-spot study of institutions located at Ahmedabad, under the administrative control of the Departmentn of Space, Bangalore. The audio-visual presentation on the activities of the laboratory and visits to few new and key laboratories were highly appreciated by the distinguished visitors.

Shri Madhavan Nair, Chairman, ISRO & Secretary, Department of Space visited PRL and inaugurated the Thermal Ionisation Mass Spectrometer laboratory on December 29, 2003.

Prof. V. Ramaswamy, GFDL, NOAA, USA visited PRL as the third *K. R. Ramanathan Professor*. During his stay he interacted extensively with PRL scientists and alsp delivered a series of lecture on cloud aerosol radiation interactions and related topics. He delivered a public talk on Global Climate Change : Past, Present and Future.

The laboratory honoured **Dr. R. A. Mashelkar**, FRS, Director General, CSIR & Secretary, DSIR with the award of the *Hari Om Ashram Prerit Senior Scien-*

tist Award for the year 2002 for his outstanding contributions in polymer science and technology.

Further PRL honoured eight distinguished scientists at a glittering function. **Dr. A. P. Mitra**, FRS, former Director General of Council of Scientific and Industrial Research graced the function and gave away the *Shri Hari Om Ashram Prerit Vikram Sarabhai Research Awards* and the *PRL Award*.

Several discussion meetings on **Quantum Information and Quantum Optics, Neutrino Physics, Science of Shallow Subsurface and Tropical Atmospheric Chemistry and Aerosols** were held at PRL.

The **73rd Annual Session of the National Academy of Sciences**, India (NASI) was hosted at Ahmedabad jointly by the Physical Research Laboratory (PRL) and Gujarat University (GU) from 10-12 October, 2003. A **National Symposium on Astronomy in the New Millennium** was also organised during this session. The Annual Session was inaugurated by *Prof. U.R. Rao*, Chairman, PRL Council of Management, and former Chairman, ISRO. A total of 340 delegates including 95 Research Scholars and Post Graduate students attended the Annual Session. *Prof. J.P. Mittal* delivered the presidential address. The scientific sessions of the Physical Sciences and Biological Sciences were held at the PRL and GU respectively. In the concluding session three young researchers were given NASI-Swarna Jayanti Puruskar for the best paper presentations.

The fourth **Workshop on Remote Sensing of Planetary Bodies** in this series was held in Physical Research Laboratory, Ahmedabad during October 19-24, 2003. Thirty four students, which comprised mostly M.Sc. Physics students, and a few research scholars, and M.Tech. and B.E. students from various parts of the country were present. The 15 lecturers presented a total of 28 lectures including 3 tutorials. The workshop programme consisted of lectures on various remote sensing techniques, and lunar and solar system studies. *Dr. K. Kasturirangan*, Honorary Member from Rajya Sabha also addressed the students. All student participants also gave fifteen minutes presentations on their ongoing research. Each participant and lecturer have been given a book "Moons and Planets" by William K Hartmann.

Schools on (a) Modeling Methods and Applications in Space, Planetary and Atmospheric Sciences and (b) Quantum Information and Quantum Optics were held at the Physical Research Laboratory. Each school was attended by large number of researchers from all over the country. Some speakers from abroad also participated.

An international conference on **Pesrspectives in Particle Physics and Cosmology** was held during the period March 30- April 3, 2004. This meeting was attended by 30 paricipants from India and abroad. Recent results in the field of neutrino physics, cosmology and gravitational waves were presented in this meeting.

A one day symposium **Crust to Cosmos : A Scientific Voyage** was held at PRL on January 24, 2004. The symposium, as the title suggests, covered a variety of topics encompassing the recent researches in various Divisions of PRL. The symposium was organised to honour Prof. D. Lal on his 75th birthday. The symposium concluded with a **Perspectives** by Prof. Lal in which he talked about emerging trends in Earth and Planetary Sciences.

PRL organised to review the progress of the *RESPOND* Programme in Space Sciences. In addition, the *Planetary & Exploration Programme* also reviewed the progress of three ongoing institutional proposals, of which one from Guahati University was completed and one each from Chandigarh University and and IIT, Kharagpur were approved to be continued. Another new institutional proposal from National Geophysical Research Institute, Hyderabad has been approved and initiated.

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 in Science was held during May 15 - July 14, 2003. The training programme aims to acquaint and expose the students with research activities of PRL. Each student was placed under the guid-

a faculty member to carry out a scientific project. Thirty three students from M.Sc. and B.Sc. and five teachers frpm colleges participated in the programme.

Under the joint venture between the *Embassy of France, Alliance Francaise of Ahmedabad and PRL*, two public lectures were arranged. The lectures entitled *Science & Society : Research, Progress & Development* and *Tele-health : Satellites & Public Health* were delivered by Mr. Emmanuel Marode, Director of Research, Progress & Development and Mr. Antonio Guell, University of Toulouse, France respectively.

The **Hindi Week** was observed at PRL from 15 to 21 September, 2003. A special event was a one day seminar on *Earth's Environment*. The Hindi Week celebration and the Seminar was inaugurated by *Prof. G. S. Agarwal. Prof. Anil Gupta* from IIM was the chief guest. He delivered a lecture on *Paryavaran, Naitikta and Sthaniya Sujbuj*. The seminar focussed on two main themes, environment technology and management. In addition, the celebrations were enlivened by essay competition, word quiz, elocution competition etc.

PRL was awarded with the *Prashasti Patra* by Town Official Language Implementation Committee, Ahmedabad for organising two 2-days Computer Training Programs in hindi at PRL during 22-25 October, 2002 under the aeges of Town Official Language Implementation Committee, Ahmedabad for the staff members of Central Govt. Deptt./Undertakings.

PRL celebrated the **National Science Day**, in association with the Indian Physics Association (IPA), Ahmedabad Chapter on February 28, 2004. The Science Day was dedicated to teachers and students from high schools. More than five hundred and fifty teachers and students from all over Gujarat attended the celebrations. **PRL Scholarships** from the Aruna Lal Endowment Fund, established by Prof. D. Lal, Honorary Fellow and former Director, were awarded to five students on the basis of their performance in Science Quiz and personal interview. All the five students are to receive Rs.5000/- per year for three consecutive years provided the students continue to study in science stream with high academic record.

PRL participated in the **State-level Exhibition** *organized by Gujarat Council of Science and Technology, Dept. of Science and Technology, Govt. of Gujarat* at the Science City, Ahmedabad, during February 28 - March 1, 2004 as a part of the National Science Day celebration. The laboratory displayed its research work as well as human resource development programmes.

I take this opportunity to thank all my colleagues including administrative, technical and supporting staff for their cooperation. I also thank the PRL Council of Management for its guidance and advice.

Director

PRL in a Nutshell

The research programmes of the laboratory can be broadly grouped under six major disciplines. These are,

i. Theoretical Physics;

ii. Nonlinear Dynamics and Computational Physics;

iii. Laser Physics and Quantum Optics;

iv. Astronomy and Astrophysics;

v. Planetary Atmospheres and Aeronomy;

vi. Earth Sciences and Solar System Studies.

The chart below profiles the scientific activities.

Some of the important research contributions are summarised.

Astronomy and Astrophysics

Star formation in starburst galaxies and in Giant Molecular Clouds in our Galaxy, stellar evolution in binary systems continue to get top priority in science programmes from A & A Division's optical and infrared astronomy group. In radio astronomy, Active Galactic Nuclei, Pulsars and the Sun's atmosphere attract attention.

The observations are being carried out regularly at the Mt. Abu Infrared Telescope using in-house fabricated instrumentation such as fast infrared photometers, polarimeters, Fabry-Perot Spectrometers and Grating Spectrograph, and state-of-the-art array detector-based imaging equipments like CCD and NICMOS 3 cameras. The radio astronomy group thrives on Rajkot IPS station as well as facilities available elsewhere. Several significant results have been obtained during the report period.

From narrow band imaging and synthetic aperture photometry it was shown that in a majority of Starburst Galaxies studied, the flux exponentially decreases radially. In some galaxies the profile flattens outwards, while in some others which show peculiar in

Profile of Scientific Activities

Basic Sciences

- Gravitation Physics & Astrophysics
- Atomic & Molecular Physics
- High Energy Physics
- Infrared & Radio Astronomy
- Laser Physics and Quantum Optics
- Nuclear Physics
- Plasma Physics
- Solar Physics
- Non-linear Dynamics
- Computational Physics
- Climate Studies

Atmospheric Sciences

- Upper Atmospheric Studies
- Middle Atmospheric Studies
- Laboratory Astrophysics
- Planetary Atmospheres

Earth Sciences & Solar System Studies

- Oceanography & Geochemistry
- Palaeoclimate
- Hydrology
- Evolution of Solar System Objects
- Cosmic Ray Prehistory
- Catastrophic Events in Earth's History
- Evolution of Indian Lithosphere

Our scientists have been utilising the national facility of GMRT since a few years for making radio observations on pulsars, giant radio galaxies as well as the Sun. The first successful solar imaging observation using the GMRT at 1060 MHz has led to the detailed understanding of a flare – Coronal Mass Ejection event that took place on 17 November 2001. This provided the first observational evidence in support of the break-out model that the reconnection process initiating mass ejection begins from the top of the coronal loop as opposed to the root of the loop. In the realm of extragalactic astronomy, the GMRT observations at 333 and 617 MHz of a giant quasar at a redshift of 1.005, revealed that this object is the largest single observed object beyond a redshift of 1(a size of 1.9 Mpc). The giant size is attributed to a lower pressure of the intergalactic medium than expected. A number of giant radio galaxies at redshift beyond 0.6 are currently being observed in order to determine their actual sizes.

Further work was carried out to resolve the enigmatic solar wind 'disappearance' event reported earlier. Extensive studies of this unusual event during which the density and velocity of the solar wind fell down to significantly low values, using solar wind velocity observations from the four-station IPS Observatory at Toyokawa, Japan. The tomographic velocity maps so obtained along with in-situ measurements of density and interplanetary magnetic field have put to rest speculation about association of such events with global, large scale phenomena such as the 11-year solar polar field reversal.

Solar Physics

The discovery of moving patterns of magnetic features within sunspot umbrae has been the most noteworthy finding this year. Although the physical origin for these motions is yet unknown, this motion seems to be pointing at a dynamical, as opposed to a static, state of the sunspot magnetic field. Similarly, the discovery of a blast-like origin for CMEs is yet another finding of a fundamental nature. Studies of the evolution of helioseismic frequencies have continued to show a variety of relationships with solar activity indices. The observation of a super active region was another highlight, while progress in the solar vector magnetograph project received a boost with the participation of MCA students of the local Mohanlal Sukhadia University, Udaipur.

Submillimeter Science and Solar X-ray Astronomy

The Submillimeter wave group of PRL has optimized the science goals and is working on conceptual design of telescope facilities by using high resolution heterodyne receivers for ground based and space born payloads. Our missions targeting 100-900 μm, with emphasis on the shorter wavelengths. This region of the spectrum is primarily sensitive to continuum and line radiation from relatively cool, diffuse media, such as interstellar and circumstellar dust and gas. In addition to spectral lines, the submillimeter band contains the bulk of the dust continuum emission from cold (T=10-20K), prestellar cores. As galaxies in the early Universe generally had a larger fraction of interstellar matter than present-day galaxies, it is very likely that such objects are very prominent in the far-IR and sub-mm band.

In context with the Indian Space Weather program, the Solar X-ray Spectrometer (SOXs) was launched onboard GSAT 2 on May 8, 2003. The payload was designed, developed and fabricated at PRL. The payload has been commissioned for regular observations since 26 June, 2003. A number of good flares has been observed. Data analysis is under progress.

Theoretical Physics & Complex System

This division is engaged in looking at fundamental problems in the fields of (1) high energy physics (2) nuclear and atomic physics (3) astro-particle physics, and (4) study of the complex systems and non-linear dynamics.

The research in neutrino physics is driven by many experimental results obtained in recent times. One specific result obtained was the realization by the group that neutrino physics experiments can help in searching for very weak forces mediated by some almost massless gauge bosons. The laboratory limits on strength of this force gets improved by several orders of magnitude by the use of the atmospheric neutrino data.

The building of linear colliders for verification of the standard model and for discovery of new physics is actively being considered. The group was engaged in the study of possible signals of CP violation at future colliders. A novel idea of the use of the transverse polarization of the e^+, e^- beams in this context was proposed.

The members of the division are actively engaged in joint collaboration with international groups. They are part of the "ACFA" (Asian Committee for Future Accelerators). Also the group members were part of a working group in a joint "APS multi-divisional study of the physics of neutrinos".

Properties of a new superfluid phase in Fermi matter termed as "interior gap", recently predicted, were studied using variational technique, specifically, energy gap, momentum distribution and elementary excitations associated with the predicted phase.

There are experimental efforts to discover strange stars – the stars containing strange quark matter. The estimation of radius (R) and mass (M) of these objects plays a crucial role in this study. The gravitational redshifts and lensing effects are proposed as a means of obtaining M and R directly in terms of the observable parameters. It is pointed out that self-lensing of the compact stars provides an important constraint on the M-R relationship.

Several studies in establishing some new directions in the applications of group symmetries in nuclei have been carried out. Firstly, a new window to the regularities of many-body systems in the presence of random forces is opened by extending the spin zero ground state dominance to the irreducible representations of a class of group-subgroup chains in various interacting boson models for collective states. Secondly, number conserving group-subgroup chains within the nuclear shell model generating isoscalar plus isovector pairing, appropriate for heavy N = Z nuclei, are identified and analyzed. Finally, a method for isospin projection, within the deformed shell model, based on the properties of symmetric group of four objects, is developed for the spectroscopy of heavy N = Z nuclei.

In an ongoing study of Rydberg atoms an accurate quantum expression of the radial dipole matrix element for radiative transition between nearby Rydberg states is derived. Upon introduction of further approximations in it, the formula of the correspondence principle method is obtained, thus clarifying the conditions under which the quantum dipole matrix element tends to the correspondence principle limit. In another work a complete solution for accurately computing the first Born amplitude for transitions connecting two arbitrary hydrogenic s-states over the entire bound-states is also given.

Stability analysis of synchronized structures in coupled map networks using both linear stability analysis and Lyapunov function have been carried out. These studies explain the observed features of the phase diagrams in various networks.

It was found that the localized states of the coupled 3-D quartic oscillator show widely varying localization lengths depending on whether the coupling strength is in the stable/unstable or the transition domain of the underlying classical periodic orbits.

The role of two-body interaction in producing chaos in rare earth elements was also studied. The energy dependent variations in the shape of the strength function in Nd, Pm, Sm, Ce and Pr were found.

Quantum Optics & Quantum Information

Major activities of this group, involve study and characterization of coherence and polarization properties of light and atomic systems; coherent control of light and of a variety of media; quantum information science; Bose condensates and ultracold systems; correlated many-body interacting systems and light beams with orbital angular momentum.

Quantum entanglement has emerged as a key resource in quantum computation and quantum information. Two or more quantum systems are entangled when their physical properties can not be expressed by means of a direct product of their respective density operators. Entanglement can be produced in a variety of systems.

Two three-level atoms in Λ configuration interacting with a two-mode cavity and the Raman adiabatic passage technique have been used for the production of four-particle entangled state. Using this, various aspects of the strong subadditivity inequality, an important inequality in quantum information theory, are studied.

It is shown how one can prepare three-qubit entangled states like W states, Greenberger-Horne-Zeilinger states as well as two-qutrit entangled states using the multi atom two-mode entanglement.

In cavity QED, it is shown that multipartite entanglement can be produced by vacuum Rabi coupling when a system of N-two level atoms in a cavity of high quality factor is driven by a strong classical field. It is even possible to produce entangled states involving different cavity modes. In Ramsey interferometry in which each Ramsey zone is represented by a quantized field in a cavity, we show that the passage of an atom can entangle the fields.

Using translational entanglement, it is proposed to investigate a realization of the position- and momentum-correlated Einstein-Podolsky-Rosen (EPR) states, that have hitherto eluded detection. These states can be created through laser-induced dipole-dipole interaction of atoms in suitable optical lattices.

A protocol for the transfer of an unknown atomic state from one cavity to a distant cavity is presented. A scheme is also proposed for quantum networking between the distant cavities based on an atomic channel. The possibility of an efficient quantum memory for the entangled states has been discussed. The entanglement can be stored in the ground states of the atom and can be retrieved as well in another cavity.

Various aspects of pulse propagation in different types of media are being investigated. It is shown that light pulses at moderate powers can be stored and retrieved. It was found that, the retrieved pulse remains a replica of the original pulse, although there is overall broadening and loss of intensity. Very interestingly it was found that, light in a Doppler broadened medium can be slowed down considerably and can even be brought to a stop. It is also shown that the pulse velocity can be tuned from subluminal to superluminal in a strongly coupled atom cavity system. Models have been developed for the propagation of intense pulses in solid state media to explain the recent experimentally observed subluminal propagation in ruby and superluminal propagation in alexandrite.

It is shown that the transmission of unpolarized light through an otherwise isotropic medium can be made sensitive to the direction of the magnetic field by the application of a suitable control field. Laser-induced breakdown of the magnetic-field-reversal symmetry in the propagation of unpolarized light has been demonstrated.

A number of few- and many-body interacting models of Calogero-Sutherland type have been studied and their relationships with decoupled oscillators have been established. A novel method of solving linear differential equations in the process has been found. This method is then used to construct coherent states for various exactly solvable potentials and for solving quasi-exactly solvable systems. Applications of the same to Hypergeometric equation and its generalizations are also illustrated.

The time evolution of a diatomic molecular wave packet for which both the vibrational and rotational motions have been taken into account have been studied. It is predicted and numerically confirmed that at certain instants of time, a suitably prepared initial wave packet will fractionally révive, that is, split up into an integer number of replicas.

A novel pulse compression technique based on exact solutions to the nonlinear Schrödinger equation (NLSE) interacting with a source, with distributed dispersion, nonlinearity and gain or loss has been demonstrated. It is shown that this model is appropriate for the pulse propagation in asymmetric twin-core fibers.

A new experimental program on local field effects has been initiated with Prof. D. Narayana Rao of Univ. of Hyderabad. Experimental results have been reported on the variation of the radiative lifetime of Eu^{3+} ion embedded in a dielectric with the refractive index n. The local field effects are studied for the first time for ions

doped in a solid glassy material. Our measurements are in agreement with the so-called real cavity model. The present measurements are free from the complications arising from reorganizational effects in solvents.

A canonical vortex was generated using a computer-generated hologram. This was converted to a non-canonical vortex using a cylindrical lens. Vortex charge inversion has been observed experimentally. The theoretical treatment of our observations was also given.

Space and Atmospheric Sciences

PRL participated in a land campaign using road network during February 7 to March 1, 2004 to measure ozone related trace gases and aerosols on the way between Ahmedabad and Hyderabad. Various analyzers, Micro Pulse Lidar (MPL), associated systems and power generators were mounted on four vehicles and measurements were made at eight rural locations each way in addition to measurements at Shadnagar near Hyderabad for about a week. The MPL and ozone and CO analyzers were also flown on one of the NRSA aircrafts and made measurements around Hyderabad on two sorties at different height levels. These are the first such measurements in India.

Higher levels of long-lived NMHCs and other pollutants have been observed at Mt. Abu which represents a free tropospheric site. Similarly, transport of pollutants like CO, O_3, NMHCs etc. from extra-tropical regions has been observed over the Bay of Bengal during February 2003 cruise.

The mobile Micro Pulse Lidar is being extensively used to study the spatial and temporal variations in the vertical profiles of aerosols and the exchange of aerosol particles between the boundary layer and the free troposphere over different environment. The lidar was also fitted in a aircraft looking downward, for the first time in the country, and the two dimensional map of the aerosol loading in and around the Hyderabad city was obtained.

An analysis of spectral aerosol optical depths measured during 1996-2000 over the Arabian Sea and tropical Indian Ocean reveals that over coastal India and Arabian Sea the aerosol optical depths in the 400-850 nm wavelength range have increased by about 5-10% per year while over the tropical Indian Ocean, the aerosol optical depths have decreased by about 20% per year.

Coordinated campaigns were conducted from the Indian MST radar site, Gadanki during April, 2003 and also during February and March, 2004 to address the coupling processes of the thermosphere-ionosphere system. During a space weather event in February, 2004, OI 630.0 nm airglow intensity registered "micro" variations even in the absence of ESF events. A new result revealing the dependence of the nocturnal 777.4 nm airglow emission on the F layer height variations on certain nights is also obtained.

Another important experiment conducted also in February 2004 is the multiple ionization cross-section measurements of Argon using INDUS-1 synchrotron at CAT, Indore. Charge states as high as Ar^{+4} were observed.

A recoil ion momentum spectrometer has been built for studying ionization of atomic oxygen and fragmentation of molecules by a laser or by electron impact ionization. The position and time information can be converted into a three dimensional velocity or momentum maps using indigenously developed software. Initial experiments have been made for Argon.

During the last year, two new initiatives were taken in the area of planetary atmospheres. The first one was to understand the chemistry and composition in the lower ionosphere of Mars. This study suggests that Mars should have permanent D-region at about 30 km due to high efficiency of the electron attachment to Ox molecules. The other initiative was to study the X-ray fluorescence (XRF) emission emanating from the lunar surface between energy range 1 to 10 KeV. The objective of this study is to predict XRF emission from various lunar terrains having different chemical compositions during phases of solar cycles 23 and 24, which is an appropriate period of the proposed Chandrayaan mission.

Planetary and Geosciences

The Thermal Ionization Mass Spectrometer (TIMS – IsoProbe-T), has been successfully installed. Several runs of Sr and Nd standards show that the machine has internal precision of about 0.0001% for Sr and 0.0006% for Nd in static mode and 0.0006% and 0.0004% in dynamic mode. After successful installation of the TIMS, Sr isotopic composition is being measured in samples from the Himalayan rivers, evaporites and carbonates to assess the role of evaporites and the precipitation of Ca in controlling the Sr budget of these rivers.

Chondrules, the once molten millimeter sized silicate spheres comprising >50% of the chondrite, are most likely formed in the solar nebula and later incorporated into their parent meteorite. An expectation of such model is that the precursors of chondrules are different from their parent chondrite. Our nitrogen isotopic studies clearly established that for ordinary chondrites this is indeed the case, while for enstatite chondrites, it may not be true.

Lunar soils have been shown to contain excess N that is non solar in origin, but its possible sources could not yet be identified. In the lunar meteorite Y983885, a low temperature released nitrogen that is heavy gives strong hints that the non solar N could be the devolatalised N from IDPs or comets that continuously bombard moon.

A second interior nitrogen component for Mars has been identified for the first time from the nakhlite Y000593. The preservation of two primitive N components in the interior of Mars, suggests that Mars interior is frozen since very early in its history.

New production has been measured in the Bay of Bengal and the Arabian Sea using ^{15}N tracer method; Even though the Bay of Bengal is only moderately productive relative to the Arabian Sea, the new production is as much as 55% in the Bay. The implications are that moderately productive ocean regions could also play a very significant role in the global carbon cycle.

A major study on the Mexican desert sequences was completed with ages ranging from modern sands to ~ 80ka. Similarly a detailed study on the desert sequences in Mohave Desert was made to compare the available chronologies using radiocarbon and cosmogenic dating with luminescence dating and examine the possible causes of differences. Both the cosmogenic ages and radiocarbon ages were substantially overestimated (20 times and 5 times) compared to luminescence ages of 2-5 ka. This study will have important ramification in the reconstruction of chronostratigraphy of the region. A detailed programme on the dating of White sands in New Mexico was taken up with the objective of developing a method of dating gypsum via luminescence and of finding the age of this unique deposit in the world. Dating of quartz extracts from the gypsum sequences provided ages of ~ 6 ka, consistent with the geological reasoning. Efforts to directly date gypsum are under way.

PLANEX

Characteristics and response of Cd-Zn-Te (CZT) detector, proposed for use in the high-energy X-ray (HEX) payload to be flown on Chandrayaan-1, have been studied in detail. Hardware and software subsystems have been developed for ground-based operation of a CZT array detector of 16cm^2 area. Integration and testing of the hardware and software subsystems is currently in progress. Based on these developments, ISRO has now entrusted the development and fabrication of the HEX payload for the Chandrayaan-1 mission to PRL in association with Space Applications Center (SAC), Ahmedabad, and ISRO Satellite Center (ISAC), Bangalore.

Technical Developments

A coelostat was fabricated in-house. A multiple power supply unit was developed for a high speed CCD camera (DALSTAR) used in adaptive optics wavefront sensor. A multiple connector cable unit for a high speed frame grabber card was also assembled. A 115 Volt, 60 +/- 0.1 Hz power supply unit was developed for use with a German equatorial mount, as part of the vector magnetograph project. A controller circuit for solar limb guider was developed for use with a 6 inch coelostat system.

New Computational Facility

Computer Centre is equipped with IBM RS-6000 SP Computer having 16 processors and 32GB RAM . Centre also has high-end graphics station, IBM RS-6000 Model 270 with 4 processors. To cater the needs of scientists, POE has also been installed on RS6000/SP and RS6000/270 machines this year. All these machines are connected to our high-speed local area network (LAN) to provide easy, fast and reliable access to all our PCs and workstations. Also, other centres at Udaipur and Abu are connected to the PRL LAN on 64 Kbps BSNL leased line. Thus full connectivity has been provided to users all the time from anywhere to the Main Campus, Thaltej, USO, and Abu. The Centre provides centralized virus free E-mails. Anti-Spam filter has been centrally installed to fight the Spam mails. The center also provides web enabled e-mail service. Center also installed one high resolution, high-speed colour laser printer and two black and white laser printers, which provides high quality, duplex laser printing to all PRL members over LAN.

Infrastructural Facilities Available

Computer Centre, Electronics Laboratory, Scanning Electron Microscope, Liquid Nitrogen Plant, Glass Blowing Facility, Radio Carbon Dating Laboratory, Thermal Ionisation Mass Spectrometer and Aluminising facility at Mt. Abu.

Research Opportunities

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

Training Opportunities

PRL organises extensive summer programmes for students 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 are considered for participating in this programme. Selected students visit PRL for two months in summer. The students are given a projects under the supervision of a faculty member. At the end of the programme they submit a report on the work carried out by them. PRL also provides project training in computer sciences and application to postgraduate students. It also offers training in electronics and computer engineering to engineering and diploma students (**Fig.2**)

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

Research and Other Scientific Details

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

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

Conferences / Symposia Convened

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

1. XXIII IUGG 2003 General Assembly, session on "Space weather Effects at Equatorial and Low latitudes", June 30-July 11, 2003, Sapporo, Japan,
   (Convener : H. Chandra)
2. Discussion Meeting on Neutrinos: at Physical Research Laboratory, August 4-8, 2003

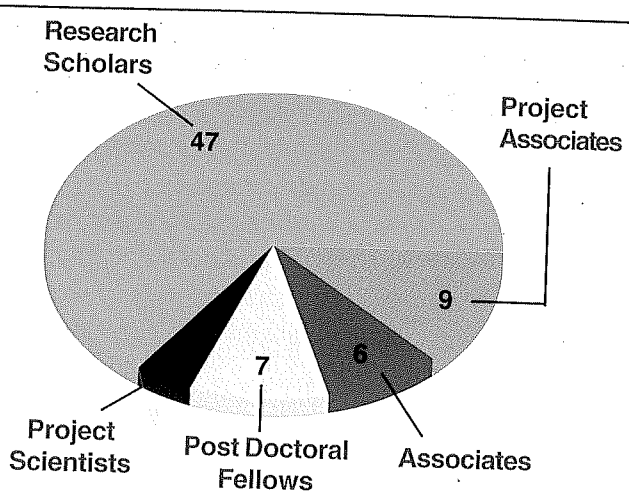

Fig.1 : Doctoral, Post Doctoral and other Programmes

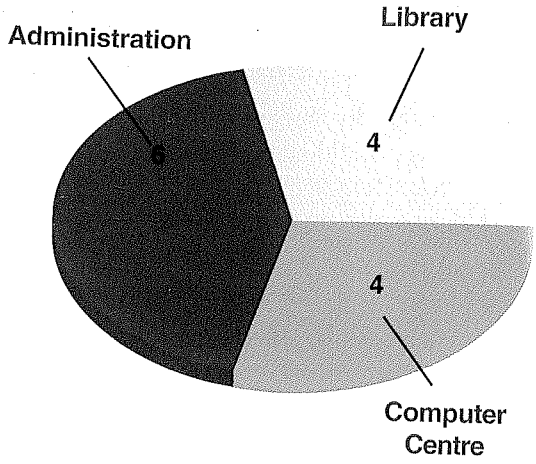

Fig.3 : Training Programme at PRL

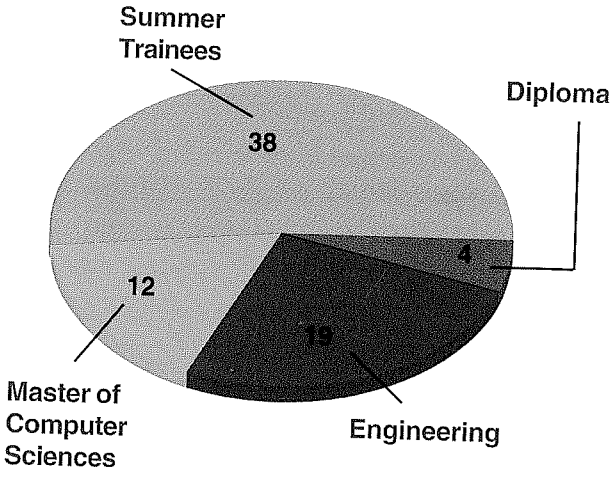

Fig.2 : Graduate & Post Graduate Programme

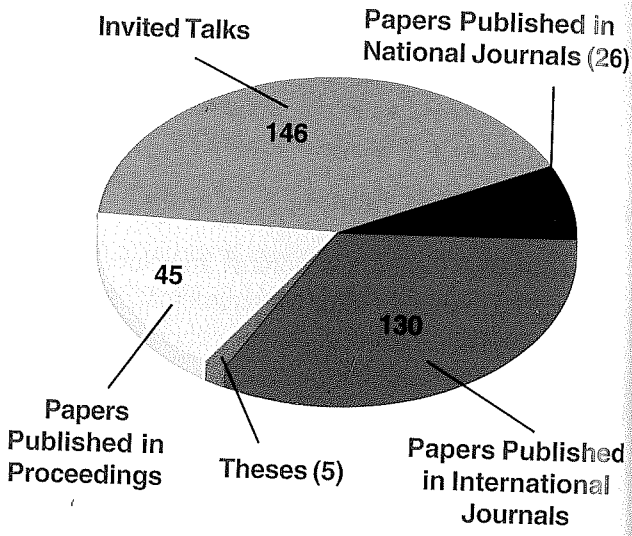

Fig.4 : Scientific Output of PRL

(Conveners : A. S. Joshipura, S. Mohanty, S. Rindani and Utpal Sakrar).

3. "Chemical Diagenetic Processes in Sediments and Sedimentary Geochemistry", in 13th Goldschimdt Conference 2003 (Japan).
(Convener : S. K. Singh)

4. SERC School on "Solar Terrestrial Environment: Space Weather", BHU, Varanasi, September 2003,
(Member Organizing Committee: H. Chandra)

5. The 73rd Annual Session of National Academy of Sciences, PRL, Ahmedabad, October 2003.
(Conveners : J. N. Goswami and S. K. Gupta)

6. National Symposium on "Astronomy in the New Millennium", in the Seventy Third Annual Session of the National Academy of Sciences, India.
(Conveners : J. N. Goswami and B.G. Anand Rao)

7. School on Modeling Methods & Applications in Space, Planetary and Atmospheric Sciences, PRL, Ahmedabad, November 10-20, 2003.
(Convener : R. Ramesh)

8. DST Workshop on Science of Shallow Subsurface, December 29, 2003.
(Conveners : S. K. Gupta)

9. Symposium on "Crust to Cosmos: A Scientific Voyage", to honor Prof. D. Lal on the occasion of his 75th birthday, PRL, January 24, 2004.
(Convener : Prof. S. Krishnaswami)

10. SERC School on Quantum Information and Quantum Optics, February 1-14, 2004
(Conveners: G. S. Agarwal and P. K. Panigrahi)

11. Workshop on "Tropical Atmospheric Chemistry and Aerosols", PRL, Ahmedabad, March 25-26, 2004.
(Conveners: S. Lal, A. Jayraman & M. M. Sarin)

12. International Conference on "Perspective in Particle Physics, Gravitation and Cosmology", at Physical Research Laboratory, Ahmedabad, 30th March – 3rd April, 2004.
(Conveners: A.R. Prasanna and S. Mohanty).

Distinguished Visitors at PRL

A **Parliamentary Committee on Science & Technology, Environment and Forests** comprising of 21 MPs from both Lok Sabha And Rajya Sabha visited PRL on September 25, 2003, as a part of the on-the-spot study of the institutions located at Ahmedabad, under the administrative control of the Department of Space (DOS), Bangalore. The activities of the Laboratory were briefed through Audiovisual presentations and visits to few laboratories.

Shri Madhavan Nair, Chairman, ISRO & Secretary, Department of Space visited PRL and inaugurated the Thermal Ionisation Mass Spectrometer laboratory on December 29, 2003.

Prof. V. Ramaswamy, GFDL, NOAA, USA visited PRL as the third K. R. Ramanathan Professor. During his stay he interacted extensively with PRL scientists and also delivered a series of lectures on cloud aerosol radiation interactions and related topics. He delivered a public talk on *(Global Climate Change : Past, Present and Future).*

The laboratory honoured **Dr. R. A. Mashelkar,** FRS, Director General, CSIR & Secretary, DSIR with the award of the *Hari Om Ashram Prerit Senior Scientist Award for the year 2002* for his outstanding contributions in science and technology. The award was presented by Prof. U. R. Rao, Chairman, PRL Council of Management. Dr. Mashelkar also delivered a lecture on *Putting Life into Gels.* The Senior Scientist Award, made biennially to an Indian scientist, was instituted with the endowment funds donated by the Hari Om Ashram Trust, Nadiad to commemorate the birth centenary of Pujya Shri Mota, the Founder of the Hari Om Ashram, Nadiad and administered by PRL. The award consists of a cash award of Rs.1lakh and a citation.

Dr. Laurent Pagani, Dr. Morvan Solez and Dr. Jean Michel Krig from Lerma Observatory de Paris, France visited the Sub Millimeter Laboratory to discuss on balloon based experiment from our national facility at Hyderabad. Prof. J. Blamont, from CNES, Paris, France; Prof. H. Newson from Univ. of New Mexico, USA and Prof. C. Koeberl from Univ. of Vienna, Switzerland visited the laboratory and gave seminars. Profs. V.K. Gaur, R.N. Singh, K.S. Yajnik, B.L. Deekshatulu, R. Navalgund and Dr. B.S. Gohil delivered invited lectures during the School on Mathematical Modelling.

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 institu-

tions 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	100
Colloquia including public lectures held	20

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.**

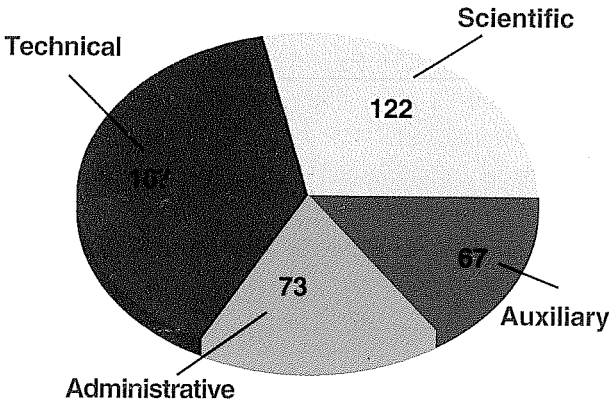

Fig.5 : Staff Structure of PRL

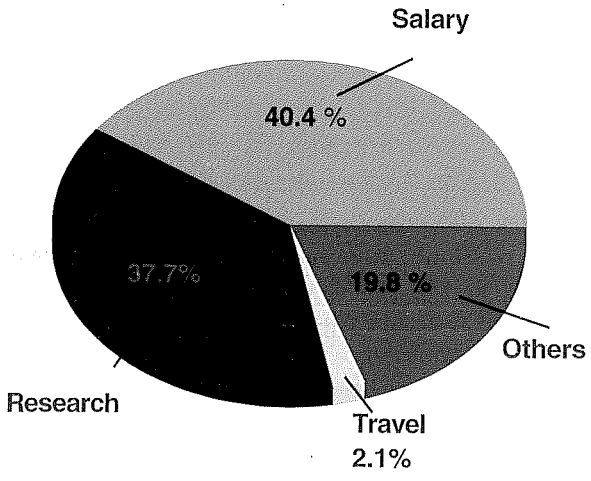

Fig. 6 : Budget of PRL

Miscellaneous

Physical Research Laboratory honoured eight distinguished scientists at a glittering function on November 11, 2003. Dr. A. P. Mitra, FRS, former Director General of Council of Scientific and Industrial Research graced the function and gave away the **Shri Hari Om Ashram Prerit Vikram Sarabhai Research Awards and the PRL Award**. Six distinguished scientists received the Hari Om Awards and two received the PRL Award. The scientists who were felicitated with the Shri Hari Om Ashram Prerit Vikram Sarabhai Research Awards for the year 2001 were *Prof. Subhasis Chaudhuri* of the Indian Institute of Technology, Bombay; *Dr. Bhabatosh Chanda* of the Indian Statistical Institute, Kolkata; *Dr. B. S. Gohil* of the Space Applications Centre, Ahmedabad; *Dr. Anil K. Pandey* of the State Observatory, Nainital; *Dr. Avinash A. Deshpande* of the Raman Research Institute, Bangalore and *Shri Mukund K. Rao* of the Indian Space Research Organisation, Bangalore. The scientists who received the PRL Awards for the year 2001 were *Dr. G. S. Bhat* of the Indian Institute of Science, Bangalore and *Dr. A. Jayaraman* of the Physical Research Laboratory, Ahmedabad. The Hari Om Awards were instituted on August 12,1974 in honour of Dr. Vikram Sarabhai, founder of Physical Research Laboratory by the Hari Om Ashram, Nadiad. The PRL Award has been instituted in 1997 from the Aruna Lal Endowment Fund established by Prof. D. Lal, Honorary Fellow and former Director of PRL. All the awards consist of a medal and a cash prize of Rs. 25,000/-.

As a part of implementation and progressive use of Hindi in PRL, the **Hindi Week** was celebrated at PRL from September 15 - 21, 2003. The highlights of the celebrations included word quiz, essay, elocution, Hamara Karya, self written poetry competitions etc.

As a part of Hindi Week celebrations, we also conducted *One Day Seminar on Prithvi Ka Paryavaran* which

was held at PRL on 17 September, 2003 in which eight speakers were invited. The key note address was delivered by Prof. G. S. Agarwal, Director, PRL. Opening talk on *Paryavaran, Naitikta aur Sthaniya Sujhboojh* was delivered by Prof. Anil Gupta form Indian Institute of Management, Ahmedabad.

Two Space Glossary Meetings were held during 6-7 June and 30-31 July and 1 August, 2003 at PRL for Editing and Enlargement of the Glossary.

The PRL was awarded with the *Prashasti Patra* by Town Official Language Implementation Committee, Ahmedabad for organising two 2-days Computer Training Programs in Hindi at PRL during 22-25 October, 2002 under the aegis of Town Official Language Implementation Committee, Ahmedabad for the staff members of Central Government Department / Undertakings.

Other activities included a training programme for the laboratory's staff; participation in Technical Seminar on *Antarix Anusandhan Aur Janhit*, held at SAC, Ahmedabad and the Condensed Translation Training Course conducted by Central Translation Bureau at TOLIC, Ahmedabad and workshops organised by various government departments.

PRL celebrated the **National Science Day**, in association with the Indian Physics Association (IPA), Ahmedabad Chapter on February 28, 2004. The Science Day was dedicated to teachers and students from high schools. More than five hundred and fifty teachers and students from all over Gujarat attended the celebrations. Two hundred and sixty nine students of Standards IX and X participated in the Science Quiz which formed the main part of the programme. Further highlights of the celebrations included talks on *Space Weather* by Dr. Hari Om Vats; *PRL's SOX Experiment* by Dr. Hemant Dave; *Recent Mission to Mars* by Dr. Deepak Dhingra and *The Indian Moon Mission* by Aparna Joshi, all from PRL. Talks were also presented on the *Diamond Jubilee Innovation Award for School Children* instituted by Council of Scientific and Industrial Research and *The Physics Olympiads* by Uma Kota, PRL.

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

Awards and Honours

1. **Prof. G. S. Agarwal** has been:
   (i) Elected as *Vice President, Indian National Science Academy, India.*
   (ii) Elected as a member of the International Advisory Committee for the Nonlinear Optics Topical Meeting, to be held on August 2-6, 2004 at the Waikoloa Beach Marriott, Hawaii.
2. **Prof. B. L. K. Somayajulu** has been elected *Fellow of Geochemical Society-European Association of Geochemistry.*
3. **Prof. J. N. Goswami** has been elected as a *Member of the Council of the Academy of Sciences*, Bangalore.
4. **Dr. K. Pande** has won the *Shanti Swarup Bhatnagar Award* for Earth, Ocean, Atmospheric and Planetary Sciences, 2003.
5. **Dr. K. K. Marhas** has won the *INSA Young Scientist Award*, 2004.
6. **Prof. Shyam Lal** has been elected *Fellow of the Indian National Science Academy*, Delhi.
7. **Prof. A. S. Joshipura** has been elected *Fellow of the Gujarat Science Academy*, Ahmedabad.
8. **Dr. R. Rangarajan** has been elected *Fellow of the Gujarat Science Academy*, Ahmedabad.
9. **Dr. P. Sharma** has been elected *Fellow of the Gujarat Science Academy*, Ahmedabad.

10. **Dr. H. S. Mazumdar** has been elected *Senior Member of Institute of Electrical & Electronics Engineers* (IEEE).

11. **Prof. R. Ramesh** has been invited by *WMO-UNEP to act as a lead author* in writing a chapter on Palaeoclimates for the forthcoming fourth Assessment Report by the Intergovernmental Panel on Climate Change.

12. **Dr. S. Ramchandran** has been invited by *WMO-UNEP to act as a lead author* in writing a chapter on Couplings Between Changes in the Climate System and Biogeochemistry for the forthcoming Fourth Assessment Report by the Intergovernmental Panel on Climate Change.

13. **Ms. S. Basu** has received *The National Academy of Sciences, India- Swarna Jayanti Puraskar* for the best research paper entitled 'Isotopic composition of nitrogen in the mantle reservoirs of earth' in October 2003, at the 73rd Annual Session of National Academy of Sciences.

14. **R.R. Mahajan and S.V.S. Murty** received the *best paper award* under the category "Astronomy, Astrophysics and Planetary Sciences", at the XIII National Space Science Symposium, Kottayam, February 17-20, 2004.

15. **A. K. Sudheer, M. M. Sarin and N. Rastogi** won the *best poster award* for "Anthropogenic sulphate rich aerosols in the marine boundary layer over Bay of Bengal" at the XIII National Space Science Symposium, Kottayam, February 17-20, 2004.

16. **The** article by **G. S. Agarwal, P. K. Pathak and M. O. Scully** in Phys. Rev. A 67, 043807 (2003) has been selected for the April 2003 issue of the *Virtual Journal of Quantum Information.*

17. The article by **G. S. Agarwal and T. N. Dey** in Phys. Rev. A 67, 033813 (2003) has been selected for the April 2003 issue of the *Virtual Journal of Quantum Information.*

18. The article by **G. S. Agarwal and P. K. Panigrahi** in Phys. Rev. A 67, 033817 (2003) has been selected for the April 2003 issue of the *Virtual Journal of Ultra Fast Processes.*

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Books/Monographs

1. J. C. Parikh, *Stochastic Processes and Financial Markets*, Narosa Publishing House, New Delhi, Chennai, Mumbai, Kolkata (2004).

2. A.C. Das, *Space Plasma Physics: An Introduction*, Narosa Publishing House, New Delhi, Chennai, Mumbai, Kolkata (2004).

3. Chandra, H., Scientific Editor, "Long Term Trends: Thermosphere, Mesosphere, Stratosphere and Lower Ionosphere", *Advances in Space Research*, **32**, (2003).

4. S. Krishnaswami, A. Jayaraman, S. Lal and M. M. Sarin (eds) Special Issue on "Aerosols and Trace Gases over the Oceans", *Ind. J. Mar. Sci.*, **33**, (2004).

5. A. K. Singhvi (ed) , "Dryland records form the Indian sub continent", *Proc. Indian National Science Academy*, **69**, 200 (2003).

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Review Papers

Solar Physics

6. S.C. Tripathy, "Recent Solar Observations", *Solar Terrestrial Environment-Space Weather*, Eds., R.P. Singh, Rajesh Singh and A.K. Singh, Allied Publishers Pvt. Ltd., New Delhi, 15-41 (2003).

Theoretical Physics & Complex System

Particle Physics

7. H.V. Klapdor-Kleingrothaus and U. Sarkar, "Consequences of Neutrinoless Double Beta Decay", Invited Article, in *Oulu 2002, Beyond the Desert*, Institute of Physics, Bristol, U.K., p.253 - 269 (2003).

Space & Atmospheric Sciences

8. Jayaraman, A. and Mitra, A.P., "The Atmospheric Brown Cloud", in the *Global Change and the Earth System: A Planet Under Pressure*, W. Steffen et al. (Eds.), p110, Springer, 2004.

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Astronomy and Astrophysics

1. C. Muthu and B.G. Anandarao, "A Spatio-kinematic Study of the Planetary Nebula NGC 1514", *AJ*, **126**, 2963-2970 (2003).

2. S.K. Chakrabarti, S. Pal, A. Nandi, B.G. Anandarao and S. Mondal, "Possible Photometric Evidene of Ejection of Bullet-like Features in the Relativistic Jet Source SS433", *Ap. JL*, **595**, L45-L48 (2003).

3. V. Venkataraman, S. Rajagopalan, P. Manoravi, A.K. Balamurugan, A. Ramalingam and A.K. Tyagi, "Formation of interface silicides at room temperature in pulsed laser deposited Ti thin films on Si <1 0 0>", *Materials Res. Bull.* (Pergamon Press) **38**, 1835-1840 (2003).

4. A. Richichi, T. Chandrasekhar and Ch.Leinert "Milliarcsecond Resolution Observations of IRC + 10216", *New Astronomy*, **8**, 507-515 (2003).

5. S. Mondal and T. Chandrasekhar, "Evidence of Asymmetric Structure in the Atmosphere of Mira Variable U Orionis from Lunar Occultation Observations in the Near Infrared", *MNRAS*, **348**, 1332-1336 (2004).

6. A. Omont G.F. Gilmore, C. Alard, B. Aracil, T. August, K.S. Baliyan, S. Beaulieu, S. Begon, X. Bertou, J.A.D.L. Blommaert and 44 coauthors, including U.C. Joshi and S. Ganesh, "ISOGAL: A deep survey of the obscured inner Milky way with ISO at 7 micron and 15 micron and with DENIS in the near-infrared", *A&A*, **403**, 975-992 (2003).

7. F. Schuller, S. Ganesh, M. Messineo, A. Moneti, J. A. D. L. Blommaert, C. Alard, B. Aracil, M. -A. Miville-Deschênes, A. Omont, M. Schultheis, and 3 coauthors, "Explanatory supplement of the ISOGAL-DENIS Point Source Catalogue", *A&A*, **403**, 955-974. (2003).

8. D. K. Ojha, A. Omont, F. Schuller, G. Simon, S. Ganesh, M. Schultheis, "Stellar sources in the ISOGAL intermediate bulge fields", *A&A*, **403**,141-154 (2003).

9. K.S. Baliyan, S. Ganesh, U.C. Joshi, I.S. Glass and T. Nagata, "Study of the Nuclear Bulge region of the Galaxy", *Astro Nach.*, **324**, 47-51 (2003).

10. K.S. Baliyan, S. Ganesh, U.C. Joshi, I.S. Glass, M.R. Morris, A. Omont, M. Schultheis, G. Simon, "A Morphological Study of the Galactic Inner Bulge", *Astro Nach.*, **324**, 53-57 (2003).

11. U.C. Joshi, K.S. Baliyan, S. Ganesh, "Polarization Studies of Comet C/2000 WM1 (Linear)", *A&A*, **405**, 1129-1135 (2003).

12. Prasad Subramanian, S. Ananthakrishnan, P. Janardhan, M.R. Kundu, S.M. White, V.I. Garaimov, "Giant Meter Wave Radio telescope Observations of an M2.8 Flare: Insights into the Initiation of a Flare-Coronal Mass Ejection Event", *Sol. Phys.*, **218**, 247-259 (2003).

13. N.M. Ashok and D.P.K. Banerjee., "The Enigmatic Outburst of V445 Puppis - a Possible Helium Nova?", *A&A*, **409**, 1007-1015 (2003).

14. D. P. K. Banerjee and N.M.Ashok., "Optical Studies of V4332 Sagittarii: Detection of Unusually Strong KI and NaI Lines in Emission", *Ap.JL*, **604**, L57-L60., (2004).

15. D.P.K. Banerjee, W.P.Varricatt, N.M.Ashok and O.Launila., "Remarkable Changes in the Near-infrared Spectrum of the Nova-like Variable V4332 Sagittarii", *Ap.JL*, **598**, L31-L34 (2003).

16. Ashok K. Singal, C. Konar and D. J. Saikia., "J1432+158: the Most Distant Giant Quasar", *MNRAS*, **347**, L79-82 (2004).

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17. P. Venkatakrishnan and B. Ravindra, "Relationship Between CME Velocity and Active Region Magnetic Energy", *Geophys. Res.Lett.*, **30**, 2181 (2003)

18. B. Ravindra and P. Venkatakrishnan, "Structure and Evolution of the Transition Region Network

Observed in He II l304", *Solar Physics*, **215**, 239 (2003)

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Solar Physics

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Submillimeter Science and Solar X-ray Astronomy

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Theoretical Physics & Complex Systems

Nuclear Physics

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Non-linear Dynamics and Complex Systems

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Quantum Optics and Quantum Information

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Space and Atmospheric Sciences

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42. A. K. Singhvi and D. Banerjee, "Luminescence dating in earth and planetary sciences: An appraisal", *Proceedings of GEOSAS-IV*, 11-26, (2003).

43. A. K. Singhvi, "Luminescence dating: basic principles and applications", in: *Late Quaternary Environmental Change: Emerging issues* (eds. Anupama, K. & Hema Achyutan), French Institute, Pondicherry, 39-41(2003).

44. B. L. K. Somayajulu, " Geochronology and paleoclimatology from continental and marine sediments using radioactive and stable isotopes", in: *Late Quaternary Environmental Change: Emerging issues* (eds. Anupama, K. & Hema Achyutan), French Institute, Pondicherry, 1-5(2003).

45. P. J. Thomas, N. Juyal, V. S. Kale and A. K. Singhvi, "Luminescence dating of fluvial sediments from Pennar river basin, south India: implications for climate change studies", in: *Late Quaternary Environmental Change: Emegring issues* (eds. Anupama, K. & Hema Achyutan), French Institute, Pondicherry, 109-110(2003)

Theses Submitted during 2003-04

1. **Soumen Mondal**

   "High Angular Resolution Studies of Late type Stars by Lunar Occultations in the Near Infrared" (2004).

2. **S. Dasgupta**

   "Studies in Coherent Control of Optical Processes" (2004).

3. **R. Rengarajan**

   "Radium isotopes and Rare Earth Elements in Indian Rivers and the Bay of Bengal" (2004).

4. **Sudeshna Basu**

   "Nitrogen and noble gases in carbonatites of India", (2004).

5. **B. Ravindra**

   "Evolution of Magnetic Field of the Solar Atmosphere", (2004).

Scientific/Technical Reports Submitted

1. **Rajmal Jain, Hemant Dave, N.M. Vadher, A.B. Shah, Vishal M. Shah, K.J. Shah, G.P. Ubale, V.D. Patel, S.L. Kayastha, K.S.B. Manian and M.R. Deshpande**

   "Pre-flight Characterization and Response of the SLD/SOXS Payload", September 2003, PRL-GSAT-2-SOXS-0185.

2. **Jigar Rawal**

   "Optimization of Internet Bandwidth Utilization", TN-2003-81.

it-0304

Invited Talks Presented in Symposia/Schools in 2003-04

Astronomy and Astrophysics

1. "Infrared Astronomy at High Resolution", in Astronomy in the New Millennium, *73rd Annual Session of the National Academy of Sciences*, PRL, **Ahmedabad**, India, October 10-12, 2003, by **B.G. Anandarao**.
2. "Remote Sensing Interplanetary Disturbances", Presented at the *Workshop on Radio and Optical Probing of the Upper Atmosphere*, PRL, **Ahmedabad**, India, February 6-8, 2003, by **P. Janardhan**.
3. "IPS Observations with the Ooty Radio Telescope" Presented at the *Symposium Entitled ORT: Past Present and Future*, Radio Astronomy Centre, **Ooty**, April 17-19, 2003, by **P. Janardhan**.
4. "Enigmatic Solar Wind Disappearance Events: Insights from IPS Observations", at the *Conference on Sun Earth Connections: Multiscale Coupling of Sun-Earth Processes*, **Hawaii**, USA, February 9-13 2004, by **P. Janardhan**.
5. "The Inner Region of the Milky Way in Infrared", *International Workshop on Cosmology and High Redshift Universe*; IUCAA, **Pune**, Feb 8-12, 2003 by **U.C. Joshi**.

Solar Physics

6. "Image Processing and Analysis Techniques", at the *IT Workshop*, MLSU University, **Udaipur**, December 29, 2003 by **Nandita Srivastava.**
7. "The Challenge of Predicting Strength of Geomagnetic Activity Related to CMEs", at the *National Workshop on Prospects of Astronomy Research in Universities*, Saurashtra University, **Rajkot**, India , February 25-27, 2004 by **Nandita Srivastava**.
8. "Recent Solar Observations", at the *Vth SERC School*, Banaras Hindu University, **Varanasi**, September 1-20, 2003, by **S.C. Tripathy**.
9. "The Active Sun and its Impact on Geo-space Environment", *National Space Science Symposium*, M. G. University, **Kottayam**, February 17-20, 2004 by **S. C. Tripathy.**

Submillimeter Science and Solar X-ray Astronomy

10. "Innovative Output Coupler for a Space Qualified SMM/FIR Laser System", presented at *11th IEEE International Conference on Terahertz Electronics -THz 2003*, September 24-26, 2003, Sendai, **Japan** by **H. Dave**.
11. "Submillimeter Astronomy", Presented at *73rd Annual Session of the National Academy of Sciences in India & Symposium on Astronomy in the New Millennium*, PRL, **Ahmedabad**, 10-12 October 2003 by **H. Dave**.
12. "High-resolution Spectroscopy for the Remote Sensing of Molecular Transitions with Sub-millimeter Wave", *National Conference on Radio Science in India- NCURSI-2003, NPL*, **New Delhi**, 27-29 November 2003 by **H. Dave**.
13. "Terahertz Technology and Applications", Presented at *1st International Conference on Microwave, Antenna, Propagation and RemoteSensing-ICMARS-2003*, **Jodhpur**, 15-19 December 2003 by **H. Dave**.
14. "Novel Approach for High Power Terahertz Local Oscillator for Space Applications", Presented at *1st International Conference on Microwave, Antenna, Propagation and Remote Sensing-ICMARS-2003*, **Jodhpur**,15-19 December 2003 by **H. Dave**.
15. "High Resolution Chirp Transform Spectrometer for Terahertz Spectroscopy", Presented at *1st International Conference on Microwave, Antenna, Propagation and Remote Sensing- ICMARS-2003*, **Jodhpur**,15-19 December 2003 by **H. Dave**.
16. "First Results from the Solar X-ray Spectrometer (SOXS)" at *25th General Assembly of International Astronomical Union (IAU)* held in Sydney, **Australia**, 13-26 July 2003 by **Rajmal Jain**.
17. "Solar Flares in Perspective of SOXS Mission" at *National Symposium on Prospects of Research in Astronomy at Universities* held at University of

Rajkot, **Gujarat**, 25-27 February 2004 by **Rajmal Jain**.

Theoretical Physics & Complex System

High Energy Physics

18. "Use of Transversely Polarized Beams", at the *Third Meeting of the Indian Linear Collider Working Group*, May 8-10, 2003, TIFR, **Mumbai**, by **S.D. Rindani**.

19. "CP Violation at a Linear Collider with Transverse Polarization", at the *6th ACFA Workshop on Physics and Detector at Linear Collider*, December 15-17, 2003, TIFR, **Mumbai**, by **S.D. Rindani**.

20. "Color Neutral Color Superconducting Quark Matter: A Variational Approach", given at *Workshop on Mesons and Quarks* held at BARC, **Mumbai**, Jan. 28-Feb. 1, 2003 by **H. Mishra**.

21. "Gapless Color Superconductivity: a Variational Approach", given at *QGP meet 03* held at VECC, Kolkata 5-7 May, 2003 by **H. Mishra**.

22. "Physics with Linear Collider", at the *Indo-US Interaction Meeting on Linear Collider and Neutrino Physics,* November 10-12, 2003, DST, **New Delhi**, by **S.D. Rindani**.

23. "Summarizing Model Predictions for Ue3", invited review talk at the *Symposium/Workshop/Meeting on Neutrino Oscillations and their Origin, NOON2004*, **Tokyo**, Feb. (2004) by **A. Joshipura**.

24. "Consequences of Neutrinoless Double Beta Decay", at *Symposium/Workshop/Meeting on Neutrino Physics and Astrophysics (NUPA04)*, IIT, **Kharagpur**, February 26-28, 2004 by **U. Sarkar.**

25. "Neutrino Masses and Leptogenesis", in *Symposium/Workshop/Meeting on Neutrino Physics and Astrophysics (NUPA04)*, IIT, **Kharagpur**, February 26-28, 2004 by **U. Sarkar.**.

26. "Constraints on Long Range Forces from Neutrino Experiments", in *Conference on Perspectives in Particle Physics and Cosmology*, PRL, **Ahmedabad**, March 29-April 3, 2004 **S. Mohanty**.

27. "Models of Baryogenesis", *Conference on Perspectives in Particle Physics and Cosmology*, PRL, **Ahmedabad**, March 29-April 3, 2004 by **R. Rangarajan**.

28. "Cosmology and Particle Physics", **two** lectures, at the Refresher Course in Experimental Physics of the Indian Academy of Sciences at Saurashtra University, **Rajkot**, November 3-16, 2003 by **R. Rangarajan**.

Nuclear Physics

29. "Bosonic U(36) and Fermonic O(8) Symmetry Schemes for Heavy N = Z Nuclei", in the *XIIIth International Symposium on Symmetries in Science*, held at **Bregenz (Austria)** during July 20-24, 2003 by **V.K.B. Kota**.

30. "Beta Decay Rates for Presupernovae Stars: Statistical Spectroscopy Method based on Two-body Random matrix Ensembles", in the *National Symposium on Neutrinos in Nuclear, Particle and Astrophysics* held at IIT, **Kharagpur (India)** during February 26-28, 2004 by **V.K.B. Kota**.

Quantum Optics and Quantum Information

31. **Inaugural Talk** and **Two** Lectures in *SERC School on Nonlinear Optics*, held on December 1-13, 2003 at Bharathidasan University, **Trichy**, by **G. S. Agarwal**.

32. "Quantum Nonlinear Optics and Control of Stimulated Raman Gain and Production of Ultra Fast Light", **Keynote Address** and **Two** Lectures in *SERC School on Coherent Optics and Applications,* held on December 8-27, 2003, at M.S. University, **Baroda**, by **G. S. Agarwal**.

33. "Controlling Polarization by Coherent Control of Anisotropies", *Conference on Polarization Optics*, June 30 - July 3, 2003, International Commission of Optics, Finland, by **G. S. Agarwal**.

34. "Microscopic Origin of Spatial Coherence" in the *Conference Tribute to Emil Wolf: Engineering Legacy of Physical Optics*, August 4-5, 2003, at SPIE meeting, San Diego, by **G. S. Agarwal**.

35. "BEC", **Four** Lectures in *SERC School on Nonlinear Optics*, held on December 1-13, 2003 at Bharathidasan University, **Trichy**, by **P. K. Panigrahi**.

36. "Quantum Optics of BEC", in *National Laser Symposium* held on December, 2003 at Indian Institute of Technology, **Kharagpur**, by **B. Deb**.

37. "Optical Vortices", **2 talks** in *SERC School on Coherent Optics and Applications*, December 8-27, 2003, at M.S. University, **Baroda**, by **R. P. Singh**.

38. "Ultra Slow Light in a Non-linear Solid State Material", in *National Laser Symposium*, December 22-24, 2003 at Indian Institute of Technology, **Kharagpur**, by **T. N. Dey**.

39. "Preparation of W, GHZ and Two Qutrit States using Bimodal Cavities", in *IInd Asia Pacific Conference on Quantum Information*, December 15-19, 2003, National University of Singapore, **Singapore**, by **A. Biswas**.

Space and Atmospheric Sciences

40. "Momentum Spectroscopy for Studying Photoionisation", at the *National Academy of Sciences Meeting*, held at PRL, **Ahmedabad** from 10--12 October 2003, by **Bhas Bapat**.

41. "Space Weather Studies", *National Workshop on Prospects of Astronomy Research in Universitie*, Saurashtra University, **Rajkot**, February 25-27, 2003, by **H. Chandra**.

42. "Space Weather" & "Ionospheric Irregularities", **five lectures**, *SERC School on Solar Terrestrial Environment: Space Weather*, BHU, **Varanasi**, September 2003, by **H. Chandra** .

43. "Ionospheric Variability", *Workshop on CAWSES*, SPL, VSSC, **Trivandrum**, September 29-30 2003, by **H. Chandra**.

44. "Effect of Solar Variability on D-region Electron Density over Magnetic Equator", in *Workshop on Three Decades of International Reference Ionosphere – A Special Session in Honour of Prof. Karl Rawer's 90th Birthday* on 2nd October 2003 at **Miltenberg**, Germany, **by S.P. Gupta**.

45. "Aerosol Studies: Challenges and Accomplishments", *Symposium on Crust to Cosmos*, 24 January 2004, PRL, **Ahmedabad**, by **A. Jayaraman**.

46. "Aerosols and Climate", *Panel on Global Warming and Environment, Indian Science Congress*, 3-7 January 2004, Punjab University, **Chandigarh**, by **A., Jayaraman**.

47. "Atmospheric Chemistry in the Anthropocene Era", at the *International Conference on Coastal and Fresh Water Issues*, 9-11 December 2003, Anna University, **Chennai**, by **A., Jayaraman**.

48. "Lidar and its Applications", at the *SERC School on Coherent Optics and its Application*, 23-24 December 2003, Appl. Phys. Dept., MS Univ., **Baroda**, by **A., Jayaraman** .

49. "Post-INDOEX Perspective and Emerging Issues", *South Asian Workshop on Air Pollution, Aerosols and Regional Impacts*, 2-4 February 2004, TERI, **New Delhi**, **A. Jayaraman**.

50. "Satellite Remote Sensing for Aerosols and Atmospheric Chemistry Studies", *Symposium on Satellite Remote Sensing for Environmental Management*, Indian Science Congress, 3-7 January 2004, Punjab University, **Chandigarh**, by **A., Jayaraman**.

51. "Aerosols over India and the Surrounding Ocean Regions: Principal Findings and Emerging Issues" at the *Workshop on Tropical Atmospheric Chemistry and Aerosols*, 25-26 March 2004, PRL, **Ahmedabad**, **A., Jayaraman**.

52. "Transport of Ozone and Related Pollutants over the Marine Regions Around India", in *ABC Science Team Meeting and South Asia Workshop on Air pollution, Aerosols and Regional Impacts*, TERI, **New Delhi**, 2-3 Jan. 2004, by **S. Lal**.

53. "Recent Advances in Ozone and Trace Gas Studies over the Tropics", *National Space Science Symposium*, **Kottayam**, Feb. 19, 2004 by **S. Lal**.

54. "Ozone and Trace Gases: Present Knowledge and Gap Areas", *Workshop on Tropical Atmospheric*

Chemistry and Aerosols, PRL, **Ahmedabad**, March 25-26, 2004, by **S. Lal**.

55. "Numerical Simulation of Equatorial Spread-F: Dependence of Background Thermosphere-ionosphere Conditions", in session *JSA03 in IUGG General Assembly held at Sapporo*, **Japan** during June 30 to July 11, by **R. Sekar**.

Planetary and Geosciences

56. "Monsoon Signatures in Trace Gas Records from Cape Rama, India", *CSIR Diamond Jubilee Workshop*, NGRI, **Hyderabad**, July, 27,2003, by **S. K. Bhattacharya**.

57. "Study of Martian Meteorites", *13th National Space Sciences Symposium*, M G University, **Kottayam**, February 17-20, 2004 , by **S. V. S. Murty**.

58. "Nitrogen and Noble Gas Studies of Meteorites and Planets", *Symposium on Crust to Cosmos: A Scientific Voyage*, January 24, 2004; PRL, **Ahmedabad**, by **S. V. S. Murty**.

59. "Solar Forcing on Past Climate", *Workshop on Climate and Weather of the Sun-earth System*, VSSC, **Trivandrum**, September 30,2003, by **R. Ramesh**.

60. "Reconstruction of Past Monsoon Rainfall using Speleothems", *National Seminar on Antarctic Geoscience and Paleoclimatology,* NCAOR, **Goa**, November 6, 2003, by **R. Ramesh**.

61. "Holocene High Resolution Paleomonsoon Studies", *International Workshop on Role of Indian Ocean in Climate Variability over India*, IITM, **Pune**, February 23-27, 2004, by **R. Ramesh**.

62. "New Prodcution in the Oceans", *National Workshop on Recent Trends in Geochemistry,* **Pondicherry** University, March 25-26, 2004, by **R. Ramesh**.

63. "Utility of Nitrogen Isotopes in Earth Science Research", at the DST Training Programme on *Applications of Stable Isotopes to Study Physiological Processes for Crop Improvement*, University of Agricultural Sciences, **Bangalore**, December 8-11, 2003, by **R. Ramesh**.

64. "A Synthesis of Climatic Record from the Indian Sub continent –Implications for Land Sea Correlations", *CSIR Diamond Jubilee Lecture*, NGRI, **Hyderabad**, August 2003, by **A. K. Singhvi**.

65. "Terrestrial and Oceanic Records of Past Climatic Changes in the Indian Sub-continent: A Synthesis", *International Congress of International Quaternary Union*, **Reno**, USA, 19. May, 2003, by **A. K. Singhvi**.

66. "Short-lived Nuclides in the Early Solar System : The Stellar Connection", *Workshop on Astronomy with Radioactivities*, Bavaria, **Germany**, May 26-30, 2003, by **J. N. Goswami**.

67. "Solar-stellar Relationship : The Isotopic View", *Symposium on Astronomy in the New Millenium*, **Ahmedabad**, October 10-12, 2003, by **J. N. Goswami**.

PLANEX

68. "Chandrayaan-1 Lunar Polar orbiter: Science Goals and Payloads", in *International Lunar Conference 2003 / ILEWG 5*, November 16-22, 2003, **Hawaii**, by **N. Bhandari.**

69. "Scientific Challenges of Future Lunar Missions", *National Space Science Symposium*, February 17-20, 2004, **Kottayam**, by **N. Bhandari**.

70. "Indian Lunar Exploration Programme", *Symposium on Lunar Exploration*, Tokyo, **Japan**, February 23, 2004 by **J.N. Goswami.**

71. "Unveiling the Mystery of the Moon: The Chandrayaan-1 Mission", *National Space Science Symposium*, February. 17-20, 2004, **Kottayam**, by **J.N. Goswami.**

72. "Gamma Rays from the Moon", *National Space Science Symposium*, February 17-20, 2004, **Kottayam**, by **D. Banerjee**

SERC School on Quantum Information & Quantum Optics

Physical Research Laboratory, Ahmedabad

1 -14, February, 2004

Name	No. of Lectures	Topic
G.S. Agarwal	7	Decoherence and its control
V.B. Sheorey	2	Entanglement and chaos
P.K. Panigrahi	2	Entanglement in solvable models
B. Deb	2	Entanglement in BECs
S. Dasgupta	1	Deutsch-Jozsa algorithm
A. Biswas	3	Quantum Logic and Entanglement
A. Gabris	1	Cavity QED based quantum computation

School on Modeling methods and applications to Space, Planetary and Atmospheric Sciences

Physical Research laboratory, Ahmedabad

10-20 November, 2003

Name	No. of lectures	Topic
P. K. Panigrahi	4	Wavelet Transforms
R. Ramesh	3	Partial Differential Equations
V. Sheel	4	Differential Equations in atmospheric modeling
S. Ramachandran	4	Modeling of Physical and Radiative effects of atmospheric aerosols
J. Banerji	4	Least squares method of Curve fitting and L curve, Tikhonov regularization.
U. C. Joshi	3	Image Analysis and visualization methods
S. C. Tripathy	4	Inversion Techniques
K. S. Baliyan	3	Emission line modeling of astrophysical environments
J. C. Parikh	2	Stochastic processes and time series.

Workshop on Remote Sensing of Planetary Bodies

Physical Research Laboratory

October 19-24, 2003

Name	No. of lectures	Topic
N. Bhandari	4	Origin of Solar System Planetary Remote Sensing Techniques Alpha Spectroscopy of Planetary Surfaces The Indian Moon Mission
J. N. Goswami	2	Neutron Spectroscopy of Planets: The search for water on Moon and Mars Recent missions to Asteriods and Comets
S. V. S. Murty	2	Surface Processes on Atmosphereless Planets Remote Sensing of Mars
R. Jain	1	The SOXS Mission
S. A. Haider	1	Modelling the Martian Atmosphere
H. S. Mazumdar	1	CdZnTe Detectors
P. N. Shukla	1	Moon: Origin and Evolution
D. Banerjee	2	Gamma Spectroscopy and X-ray Flourescence methods: Application to Chemical Mapping of Planetary Surfaces Recent Lunar and Martian Missions
J. S. Ray	1	Geology of Inner Planets
D. Dhingra	1	Mineralogical Mapping of Planets

Science at PRL

A Study of Carbon Monoxide Bands in AGB and Post-AGB Stars

The first ($\Delta v = 2$) and second ($\Delta v = 3$) overtone bands of CO molecule in the K and H bands in the AGB/ Post AGB stars are important diagnostic signatures for studying the mass loss processes in the atmospheres of these stars. Using NICMOS 3 near-infrared spectrograph at Mt. Abu, we have obtained H and K band spectra on about 50 stars and the equivalent widths of the CO bands were estimated. The study aims at finding the possible variation in these bands with the evolution of these intermediate mass stars and thus understand the progression of mass loss.

(B.G. Anandarao and V. Venkataraman)

Investigation of Massive Star Forming Regions

Massive star forming regions are difficult to study due to their relatively large distances (> 1 kpc) and short evolutionary time scales compared to low mass star forming regions. A campaign has been initiated to study the IRAS identified Ultra-Compact HII regions associated with massive stars in small clusters. Near-infrared JHK' photometry and narrow band imaging in Br γ and H_2 1-0 S(1) lines were made on about 10 such sources that are believed to be powered by intermediate - high mass stars. The idea is to classify pre-main sequence stars and estimate their masses to obtain initial stellar mass function using color-color and color-magnitude diagrams; also to identify molecular outflows from these massive star forming regions to investigate the energetics of such flows. Some of these sources are being studied in radio continuum also using GMRT facility (in collaboration with TIFR). The radio observations would yield density parameter that is important for estimating the extinction in the cluster.

(B.G. Anandarao and V. Venkataraman)

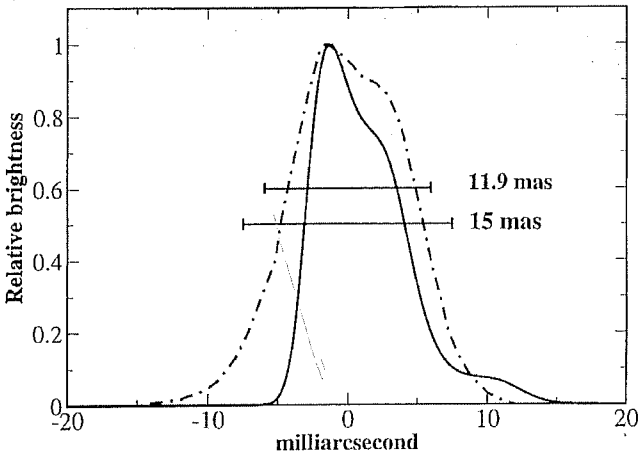
Evidence of Asymmetric Structure in the Atmosphere of Mira Variable U Orionis from Lunar Occultations at 2.2 microns

Mira variables have complex and very extended atmospheres with spherical symmetry in general but departures from this symmetry are known. Repeated occurrences of spatial asymmetries, large chromatic size variations near deep absorptions due to TiO or VO, evidence of clumps and hotspots in Mira atmospheres have been reported either by ground based direct imaging using aperture masking methods or though Hubble Space Telescope (HST) imaging in optical/UV. Near simultaneous lunar occultation observations, separated by only a few hours in the same wavelength band, sample different diameters across a source at high angular resolution and can thus pinpoint existence of spatial asymmetries independent of phase variations. From our lunar occultation observations on Mira variable U Orionis carried out at Gurushikhar in the K band, we derive a model independent brightness profile with a marked asymmetry in both near central and outer regions (~ 2 R_*). In comparison, similar K band occultation observations carried out on the same day but at a different position angle also show asymmetry in the source but to a lesser extent. The uniform disk angular diameters derived in the two cases 11.9 ± 0.3 mas (our PA=136°) and 15.14 ± 0.05 mas also underscore this spatial asymmetry. We derive a picture of U Ori as a spatially asymmetric source which shows an ellipsoidal elongation at position angle ~ 70° with semi minor axis to semi-major axis ratio of 0.77. The same ratio is obtained for the OH Maser extended emission around U Ori at 1665 MHz. Corollary evidence for asymmetry also comes from the direction of maximum optical polarization around U Ori **(Fig. 1.1)**.

(Soumen Mondal and T. Chandrasekhar)

Asteroid Occultation

Asteroid occultations of stellar sources provide a direct measurement of the length of a chord across the asteroid with excellent precision. The measurement is also independent of the brightness of the asteroid as well as the location of the asteroid anywhere in the solar system. These events can also pinpoint if any occulting asteroid has a binary structure. The occultation of star TYC 5030-0054-1 (SAO 141390) (m_v =9.1, m_J=6.8) by mainbelt asteroid 747 Winchester was successfully observed at Gurushikhar on 4 June 2003. The event was observed in the NICMOS subarray mode of 20 x 20 pix



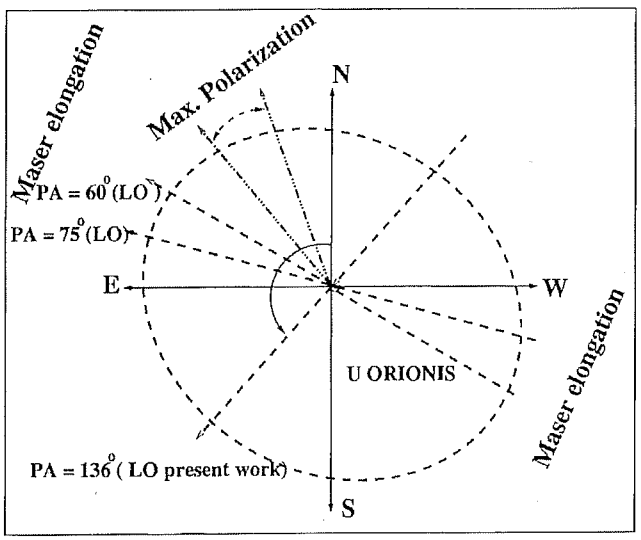


Fig. 1.1 : Top: The one dimensional high angular resolution brightness-profile derived from K band lunar occultations of U Ori at Gurushikhar (thick line, PA=136°) and at TIRGO Observatory (dashed line PA=75°) on the same day. Bottom : Position angles of all lunar occultations on U Ori along with corollary evidence for asymmetric structure like Maser elongation and direction of intrinsic maximum polarization.

in the J band (1.25μ m). The field of view of the subarray on the sky was ~ 20"x20". The sampling time was 200 ms; 870 frames were recorded in a 3 min interval centered on the predicted time of event. The event occurred 10s later than predictions and was clearly recorded (**Fig. 1.2**). In addition, the event was also recorded in the optical region with a video rate CCD attached to the 6-inch finder telescope. A clear dip is recorded in both

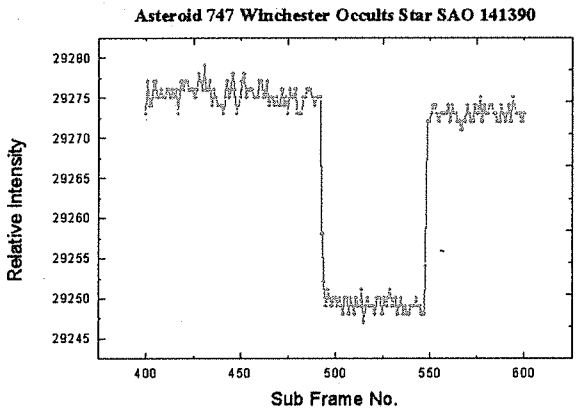


Fig. 1.2 : Asteroid occultation in the J band on 4 June 2003 recorded using a NICMOS subarray.

modes of observation. The duration of event 11.8 ± 0.2 sec results in a chord length across the asteroid of 201 ± 3 km.

(T. Chandrasekhar, P.K. Kikani and R.R. Shah)

International Blazar Monitoring Campaigns

Apart from our ongoing program of monitoring a sample of blazars using near infrared camera, NICMOS-3 and optical polarimeter, we also participated in the international Campaign, "WEBT (Whole Earth Blazar Telescope)" on 3C66A, AO235+16, PKS 0716+714 and Mrk 421. These campaigns aim at monitoring these sources in various wavelengths - from radio to Gamma rays - for a continuous and simultaneous coverage. Most of these sources are in very bright phase. Knowledge of the variability at various time scales and at different wavelengths helps to understand the physical mechanisms responsible for their energy generation. Mrk 421 is in very bright phase and very stable too. The possible explanation for such phase could be injection of substantial energy in a large region, which remains stable for long period of time. PKS 0716+714 is showing overnight variations along with long term variation. This source had shown brightest phase ever recorded which we have detected in near infrared bands from Mt Abu.

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

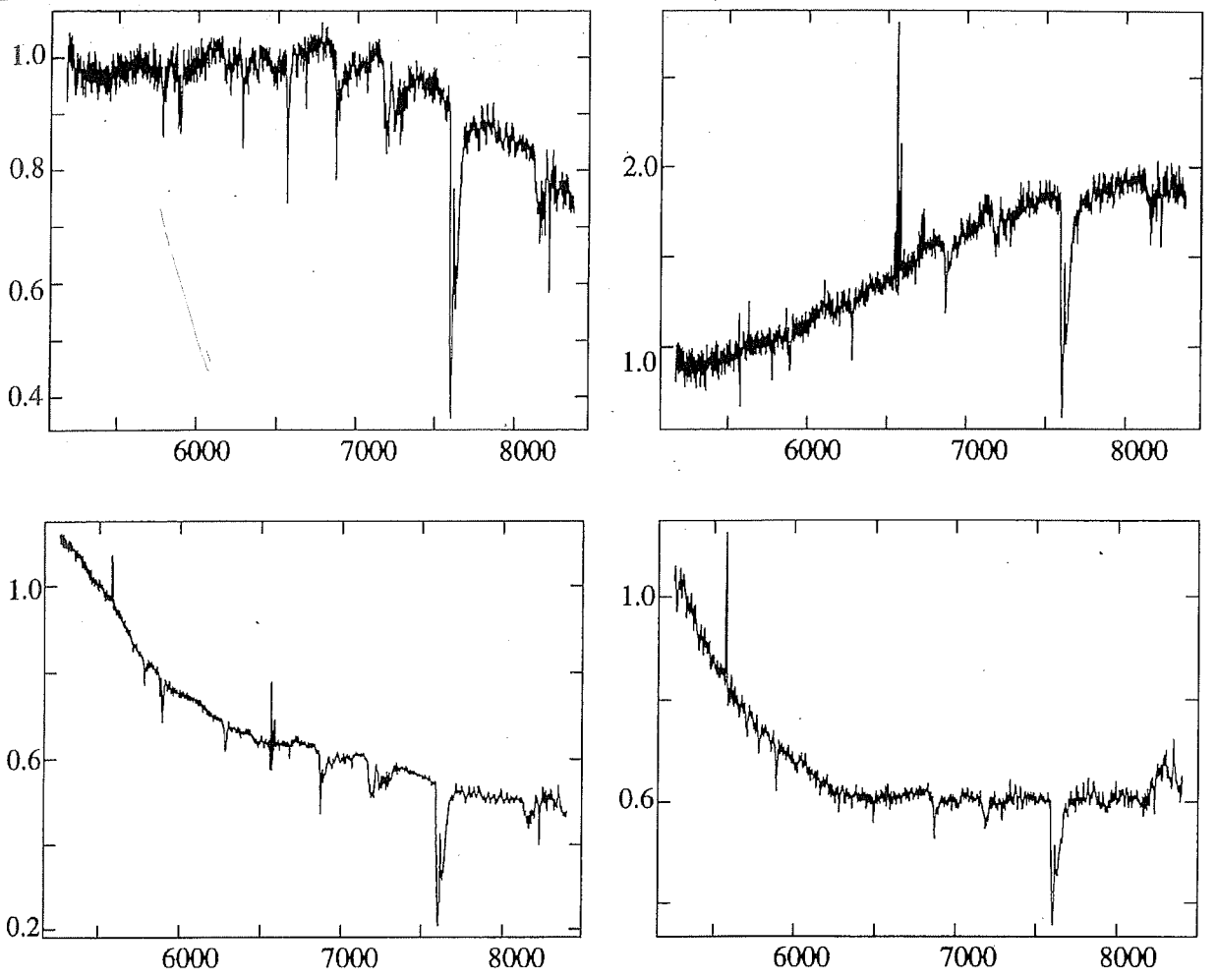


Fig. 1.3 : HCT optical spectra of a sample of stars used to characterise and identify post-AGB stars, young stars and HII regions, some with strong emissions.

Study of the Inner Regions of the Milky Way

Under an Indo-French collaborative Project, a catalogue of more than 100,000 sources in the inner regions of the Milky Way was made. From the study of these sources many peculiar sources were noticed. A large number of these sources were seen to have large IR excess. To understand these sources, photometry information in mid-IR and near-IR was not enough. In an attempt to characterize this large stellar population, with large IR excess detected in ISOGAL and other surveys, a large observational program of optical spectroscopy was taken up at the Himalayan Chandra Telescope at Hanle. Spectral information is necessary to distinguish evolved and young objects, in addition to photometry. A large body of observations – comprising of more than 150 spectra - were taken in several runs in 2003. We find several sources showing strong emission lines (**Fig. 1.3**). Their nature is being investigated and the detailed data analysis is underway.

(S. Ganesh, K S Baliyan and UC Joshi)

Polarization Studies of Comet C/2000 WM1 (LINEAR)

Linear polarization observations were carried out on comet C/2000 WM1 using a photopolarimeter mounted at the 1.2 m telescope at Mt. Abu Observatory

during the month of November 2001 and March 2002. The observations in November cover the low phase angle when the polarization is negative and where the data for most of the comets are rather meager. The observations during March were made when the phase angle was 47 degree. Observations were conducted through the IHW narrow band and BVR broad band filters. This study led to the following conclusions: i) Comet C/2000 WM1 belongs to high polarization class i.e. the dusty comet family; ii) The negative branch of polarization is explained to be due to the scattering by the aggregate grains with monomer size comparable to the wavelength. The mutual influence of the monomers composing aggregate particles produces the negative polarization. The present observations are explained if the monomer size parameter is close to 1.5 and refractive index close to (1.65 + 0.05 i). Dust grains are composed of silicate core and organic mantle; and iii) On March 17, 2002 comet C/2000 WM1 was seen to be very active showing strong emission in C2.

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

Studies of the Nova-like Source V4332 Sagittarii

We have studied the enigmatic nova-like variable V4332 Sgr in the optical and near-infrared regions. This object is important since it is considered to be the possible prototype of a new class of eruptive variables. V838 Mon - which had a spectacular eruption in 2002 - is thought to be another member of this class. The cause of the outburst in such objects is not well understood. Our recent spectra of V4332 Sgr, taken after a gap of 10 years since the objects outburst in 1994, show striking developments in the optical and near-IR. The optical spectrum - taken from the Himalaya Chandra Telescope, Hanle - shows several lines in emission but is dominated by exceptionally strong mission in the resonance doublet of KI at 7665 and 7699 Å and to a slightly lesser strength in the NaI doublet at 5890 and 5896 Å. The KI lines appear to be the strongest ever seen in any astronomical object. The near-IR spectra (taken from UK Infrared Telescope, Hawaii) show several molecular bands of AlO - a rarely seen molecule in astronomical sources. Many of these AlO bands are being detected for the first time. The formation of a new dust shell is also detected. These various observational aspects have allowed us to investigate the site of origin and the mechanism of excitation of the different atomic and molecular species that are seen. The data also throws light on the nature of the outbursting progenitor and the cause of the outburst. The object appears to be different from classical novae or other classes of eruptive variables. Specifically, the presence of a cold molecular environment in V4332 Sgr is not expected in classical novae ejecta. A better understanding of such objects will be achieved through further observations (which are just completed) in the L and M bands in the near-IR and also in the milli-meter region. This work was done in collaboration with W.P. Varricatt, JAC, Hawaii and O. Launila, SCFAB-KTH, Sweden.

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

Radio Galaxies and Quasars

About half a dozen giant radio galaxies and quasars (with radio sizes > 1 Mpc) were observed with the GMRT. These are at relatively high redshifts ($z > 0.6$). The objective of these observations was to investigate the possibility of detecting a bridge of emission at low frequencies, which may be suppressed due to inverse-Compton losses against the cosmic microwave background radiation. In our previous observations, we found a giant quasar J1432+158, which presently is the largest single object known beyond a redshift of 1. In this quasar we detected a jet-like structure connecting the core to the western hotspot, while the eastern hotspot is found to be largely tail-less with no significant bridge emission (**Fig. 1.4**). The estimated life-time for the radiating electrons in the tail of the western lobe appears smaller than the travel time of the radiating particles from the hotspot, suggesting either in-situ acceleration or dissipation of energy by the jet at this location. The pressure of the intergalactic medium at $z \sim 1$ estimated from the minimum energy density calculations appears to be somewhat lower than the value extrapolated from nearby giant radio galaxies.

(Ashok K. Singal)

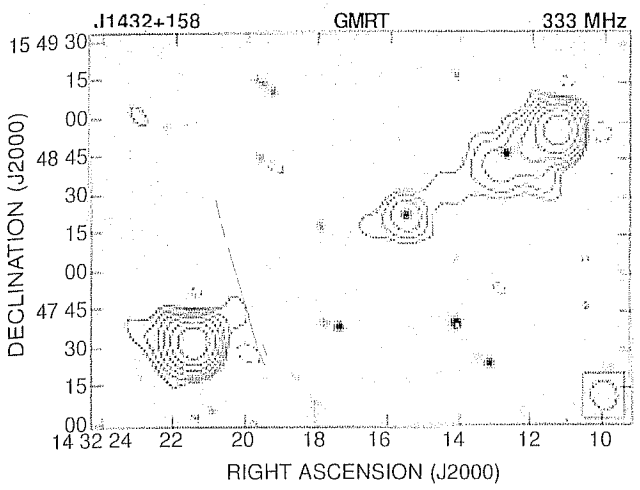


Fig. 1.4 : The 333-MHz image with an angular resolution of 11.4 x 10.3 arcsec² along a position angle of 24° is shown superimposed on the optical field.

Soft Gamma-ray Repeaters and Anomalous X-ray Pulsars

Anomalous X-ray Pulsars and Soft Gamma-ray Repeaters are a class of high-energy sources, which have recently been identified as highly magnetized neutron stars. Radio pulsations from these objects have not been reported so far. A pilot project to detect radio pulses from such sources using the GMRT has been initiated and three of these objects were observed with the GMRT in a phased array mode. The data reduction is in progress.

(Ashok K. Singal)

Resolving the Enigmatic Solar Wind Disappearance Event of 11 May 1999

On May 11 and 12, 1999, the Earth was engulfed by unusually low density (<1cm^{-3}) and low velocity (350kms^{-1}) solar wind for a period of over 1 day. Extensive studies of this unusual event, that occurred during Carrington Rotation 1949 (CR1949), using both ground-based and space-based in-situ observations have not, as yet, been able to identify the cause or the solar source of this event. Using solar wind velocity measurements from the four-station IPS observatory of the Solar-Terrestrial Environment Laboratory (STEL), Toyokawa, Japan, we investigated the structure of the solar wind, in May 1999, during CR1949. IPS observations from STEL were used to make tomographic velocity maps to identify and delineate the extent and morphology of the stable solar flows, during CR1949, in the vicinity of the Earth. Combined with in-situ measurements of the interplanetary magnetic field (IMF) and potential field computations of the solar magnetic fields in the period, we have identified the source region of the unusual flows and have shown that the flow responsible for the "disappearance event" was a stable uni-polar flow originating in the vicinity of a large mid-latitude active region AR8525, located at ~18°N and between heliographic longitudes 280° and 300°. It has been speculated that such events may be caused by the large scale restructuring of the solar magnetic field at the maximum of each solar cycle. However, pinpointing solar source and nature of this event has put to rest speculation about the association of such events with global, large-scale solar phenomena like the periodic 11-year solar polar field reversal. This work was carried out in collaboration with Prof. M. Kojima, STE Laboratory, Japan.

(P. Janardhan)

Imaging a Solar Flare-CME Event using the GMRT

We have made some of the first successful GMRT observations of a solar flare-CME event using GMRT observations at 1060 MHz in conjunction with data from the Nobeyama Radio Heliograph (NoRH), the Hiraiso Solar Observatory and the Large Angle Spectroscopic Coronograph (LASCO). An M2.8 flare observed at 1060 MHz with the GMRT on 17 November 2001 was associated with a prominence eruption observed at 17 GHz by the Nobeyama radioheliograph and the initiation of a fast partial halo CME observed with the LASCO C2 coronograph. Towards the start of the eruption, we found evidence for reconnection above the prominence. Subsequently, we found evidence for rapid growth of a vertical current sheet below the erupting arcade, which is accompanied by the flare and prominence eruption. The analysis lead to new insights into the onset mechanism

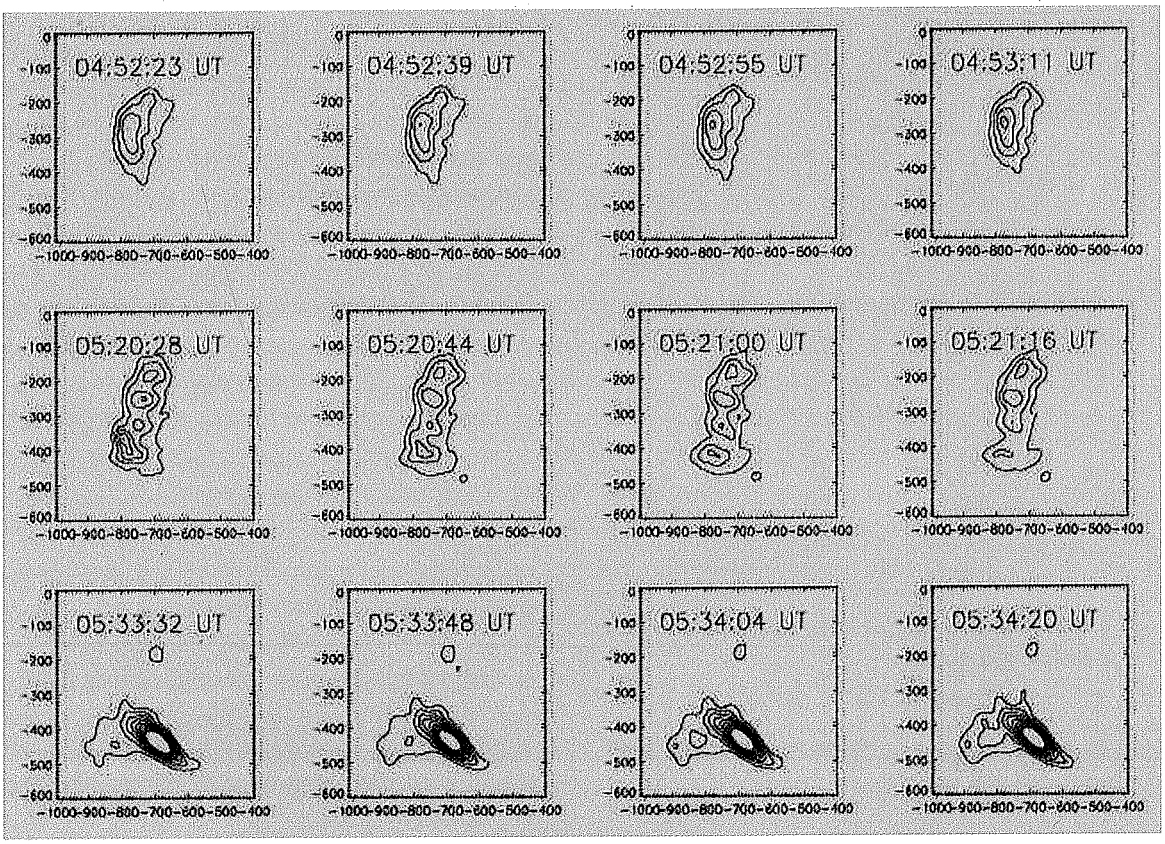


Fig. 1.5 : Contours of 16s snapshots of the GMRT 1060 MHz emission. The center of these images is at S15E46 and the field of view is 500"x500". The restoring beam is 34"x24". The contour levels are 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0 times the flux at the largest peak, which occurs at 05:33 UT. The 3 sets of 16s snapshots start at 04:52:23 UT, 05:20:28 UT and 05:33:32 UT corresponding to the three peaks of the 1060 MHz lightcurve. The emission at the peaks at 04:52 UT and 05:20 UT are from a NS oriented loop system, whereas the emission at the peak at 05:33 UT is from a NE-SW oriented loop. The brightness temperature of the emission at each of these peaks is ~108 K.

of a flare-CME event that could be construed as evidence in favor of the magnetic breakout model. **Fig. 1.5** shows a sample of GMRT snapshot images of the flaring region, while **Fig. 1.6** shows the light curve obtained from the GMRT observations. This work was carried out in collaboration with Dr. Prasad Subramanian, IUCAA, Pune and Dr. S. Ananthakrishnan, GMRT, Pune, India.

(P. Janardhan)

Magnetopause Variations

Using ACE level II data of solar wind density and velocity along with the model of geomagnetic field, we estimated magnetopause position from the Earth. For a very peculiar situation reported during May 11-12, 1999, as "solar wind disappeared", the magnetopause position varied drastically. It is found that during normal time, the position of magnetopause is ~10 R_E (R_E is the radius of the Earth). However, during this solar wind disappearance event it increased from its normal position to more than 100 R_E. The magnetopause moved away with an average rate of 5.4 km/sec for almost 33 hrs and remained at very large distance for over two hours. It returned to its almost normal position in just two hours receding back at the rate of 75 km/sec. These estimates are in agreement with the findings of others,

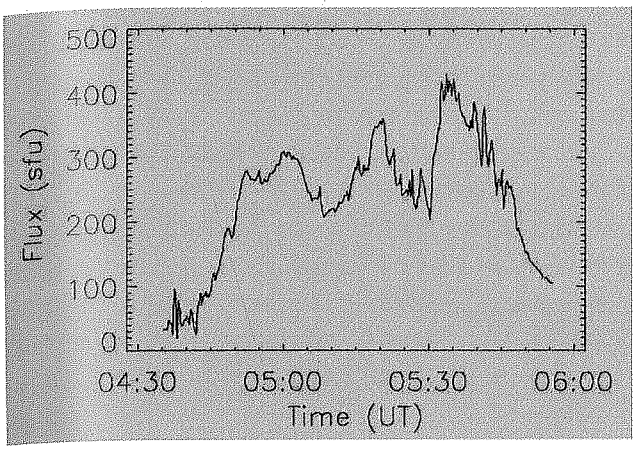


Fig. 1.6 : The 1060 MHz lightcurve from GMRT observations. The three peaks are clearly evident. The first onset of nonthermal emission at this frequency occurs at 04:48 UT. The peak of this lightcurve is normalized with respect to the peak of the 1 GHz lightcurve from the NoRP (http://solar.nro.nao.ac.jp/norp/html/daily/).

wherein it is repored that during 1730 - 1936 UT on May 11, the bow shock crossed the location of WIND. Thus, bow shock must have at least moved out beyond 58 R_E during this period. The present work gives more quantitative values of magnetopause position and its variation during this event. The ACE level II observations reported here indicate a six order of magnitude decrease in the solar wind pressure and ten fold increase in the magnetopause position. These as well as Bz and Dst support the view that this solar wind disappearance event was due to the passage of a void and not void-within-a-void. The sustenance of the void and several associated geophysical phenomena are yet to be understood. The Bz component of IMF remained quiet during the event, however it showed a fast and intense fluctuations after the passage of this low solar wind region or "void". The equatorial Dst values indicate a mild geomagnetic storm after the passage of void. This is probably due to (i) the accumulation of more solar material at the boundary of the tenuous region which exerted higher RAM pressure on the geomagnetosphere and (ii) fluctuations (-12 to 9 nT) in Bz.

(Hari Om Vats)

April 4, 2000 Solar Event and its Space Weather Effects

There was a very interesting solar event on April 4, 2000 which began with the disappearance of a large filament and 2F/C9 flare from the active region AR NOAA 8393. These were quickly followed by wide partial halo CME. The interplanetary effects of the CME were observed by the IPS observations using 103 MHz radio telescope at Rajkot. LASCO estimates of the CME showed it to move fast with a speed of 1188 km/s. However, IPS observations indicate that solar wind enhanced from ~ 300 to 475 km/s. The ACE measurements showing solar wind enhancement from 375 to 575 km/s are in the vicinity of IPS measurements. This CME took nearly two days to arrive and create a strong geomagnetic storm, which had a sudden commencement (SSC) and the equatorial Dst reached ~ -288 nT. This was one among the seven largest storms in the history of equatorial Dst measurements. This was a typical space weather event, which produced a strong spread-F and the associated charged particles produced aurora in a much-extended region beyond the regular auroral zone. This work was carried out in collaboration with Prof. K. N. Iyer and his colleagues of the Physics Department of Saurashtra University, Rajkot

(Hari Om Vats)

Homologous Solar Flares

The tendency of recurrence of the solar flare within an active region is termed as "Homologous flares" - some of these events appear twice or several times in the same location and with similar shape. On June 12, 2000 while monitoring the Sun through a 15 cm refractor at State Observatory Nainital, three homologous flares were observed. The observations consisted of 1600 images with exposure time of 50 ms. In the four hours of observing, these flares took place within 41 x 73 arc second of the solar surface in the active region AR NOAA 9033. The power spectrum analysis of the intensity plot gave a periodicity of 26.7 min that may be the time for active region to store the magnetic energy which is released in the form of solar flares. This work was carried out in collaboration with Dr V. K. Verma of State Observatory, Nainital.

(Hari Om Vats)

Space Weather Studies

Blast Wave Origin for CMEs

The total magnetic energy of several active regions that produced CMEs was plotted against the speed of the CMEs. The speed, as measured from LASCO data, was seen to be proportional to the 1/5th power of the magnetic energy. This behaviour is exactly similar to that of a blast wave's dependence on the blast energy. Physically, a blast like situation can arise, since the time taken for magnetic restructuring in the corona (150 s) is much smaller than the relaxation time of the corona (1000 s). Thus, this study resurrects the case for a blast like origin for a CME.

(P. Venkatakrishnan and B. Ravindra)

Conditions Leading to Eruptions of CMEs Associated with Eruptive Filaments

Observations of coronal mass ejections (inner coronal data were recorded from Mauna Loa Solar observatory (MLSO) and white light observations from the LASCO/SoHO) associated with eruptive filaments recorded in H-alpha. From the analysis of 4 such events, we found that the height of the onset for these CMEs ranges from 1.3-1.5 R_S. The pre-eruptive scenario of these CMEs as seen in FeX and FeXIV emission line is marked by features which can be identified with the three-part structure of the white-light CME observed in the outer corona. The ascent of these CMEs is very slow (<100 km/s) in the lower corona, so that the actual onset time is difficult to define. Major restructuring of the magnetic field close to the source region has been identified as the only cause for the eruption of the CME. Observations also support the fact that a common process drives both the CME and the associated prominence.

(**Nandita Srivastava**, Joan T. Burkepile and Tony A. Darnell)

Solar and Interplanetary Sources of Major Geomagnetic Storms during 1996-2002

Our statistical investigation of the solar sources of the intense and super-intense geomagnetic storms that occurred during 1996-2002 reveals that fast halo CMEs that are associated with flares and originate in central and mid-latitudes of the sun can possibly be used for predicting intense geomagnetic activity with some degree of confidence. The investigation further indicates that none of the other solar sources can be used as a significant predictor in space weather forecasting. The prediction of the strength or the magnitude of geomagnetic storms early on, depends on the prediction of the ram pressure. Ram pressure can only be weakly predicted early on with the knowledge of projected initial speed of the CMEs. Our analysis shows that one requires knowledge of the densities of the CME and its variation through the IP medium, for a better prediction of the ram pressure. From the regression analysis of the 64 events, observed during 1996-2002, we found a linear relation between the transit time and the initial speed. This relation is useful for predicting the arrival time of the geoeffective CMEs.

(Nandita Srivastava and P. Venkatakrishnan)

Predicting Intensity of Intense Geomagnetic Storms from Solar and Interplanetary Properties of CMEs: A Statistical Model

A statistical model based on logistic regression for predicting the occurrence of intense geomagnetic storms has been developed. Our study has shown that the strength of the resulting geomagnetic storms depends upon various solar and interplanetary properties. Total 64 geo-effective events recorded during 1996-2002 were used for determining the parameters influencing the magnitude of the resulting geomagnetic storms. 60% of the events recorded were used for determining the model parameters while the rest 40% were used for validating the model. The input independent model variables, which include a number of solar and interplanetary factors, were regressed against a binary dependent variable viz. occurrence of the intense geomagnetic storms. The model predicts 90% of the training events correctly and 85% of the validation events correctly. The results indicate that the logistic regression model can be effectively used for predicting the strength of the geomagnetic storms.

(Nandita Srivastava)

Magnetic Evolution of Super-active Region NOAA AR 10486 and the Large 4B/X17.2 Class Flare Observed during October 28, 2003

Extensive flare activity was observed in super-active region NOAA10486 during its disk passage of October 22-November 04, 2003. An extremely energetic 4B/X17.2 flare on October 28, 2003/11:10 UT was observed from USO when the active region was located at S16E08, i.e., close to the disk-centre. This flare was rated the third largest X-ray flare recorded by GOES satellite, and the largest in the optical class (4B) observed so far from USO. Chromospheric H-alpha filtergrams were obtained before, during and in the decay phase of the two-ribbon flare at a cadence of 3-4 seconds. The temporal and spatial structure evolution was analyzed with the help of a movie constructed using more than 4000 images. Magnetograms from NASA-MSFC showed large magnetic shear around the flare site which was delineated by a large active filament. The filament erupted as the flare progressed. In the decay phase of the flare, a system of post-flare loops developed at the site of the erupted filament. Observation from TRACE also exhibited these loop structures. The spatial and temporal development of the flare is shown in **Fig. 2.1**. (see title page) Associated with this flare, a fast Earthward moving halo CME was also detected by SOHO, which initiated a major geomagnetic storm on October 29, 2003 at 06:13 UT, i.e., within a record time of 19 hours after the flare. This large flare was followed by another 2B/X11 event on October 29, 2003/20:49 UT, not observed from USO as it occurred in our night-time. We have used white light full disk images and line-of-sight magnetograms obtained from SOHO-MDI for determination of proper motion of the main sunspots and corresponding magnetic fluxes in order to understand rapid magnetic energy build-up in the active region, giving rise to the two large flares within such a short time.

(Ashok Ambastha)

Solar Magnetism

The Pattern of Moving Magnetic Inhomogenities In and Around Sunspots

High resolution MDI magnetograms are used to study the pattern of motions of magnetic features in sunspots. We examine the inward and outward moving features in sunspots. The velocity of these features is small in the umbra while it is about 0.5 km/s in the outer penumbra (**Fig. 2.2**). The inward and outward moving features may be the possible origin for the multi timescale fluctuations of magnetic field strength in sunspots.

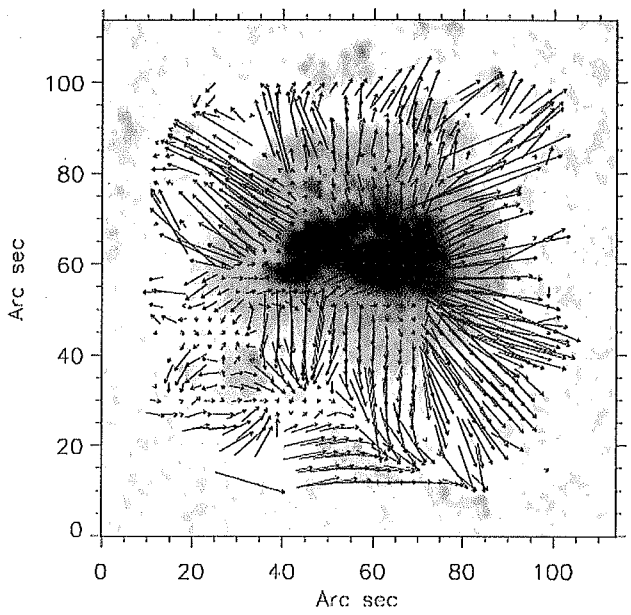


Fig.2.2 Map of horizontal motion patterns of magnetic features in the active region overlaid upon the intensity image of AR 8133. The maximum length of the arrow corresponds to a velocity magnitude of 0.8 km/s.

(B. Ravindra, P. Venkatakrishnan and Brajesh Kumar)

Simultaneous Stokes-V Diagnostic of a Sunspot using Mgb and Fe I lines

Simultaneous observations of Stokes profiles in photospheric Fe I (630.15 nm and 630.25 nm) and chromospheric Mg I b1 and b2 (518.4 nm and 517.3 nm) lines over a sunspot are presented (**Fig. 2. 3**). Observations were carried out using the Advanced Stokes Polarimeter of HAO/NSO,VTT, SacPeak, U.S.A. The Stokes-V amplitude asymmetries for these lines are analyzed. The values of amplitude asymmetry in Mg b lines are negative in disk-center-side penumbra while they are positive in limb-side penumbra. This trend is similar in

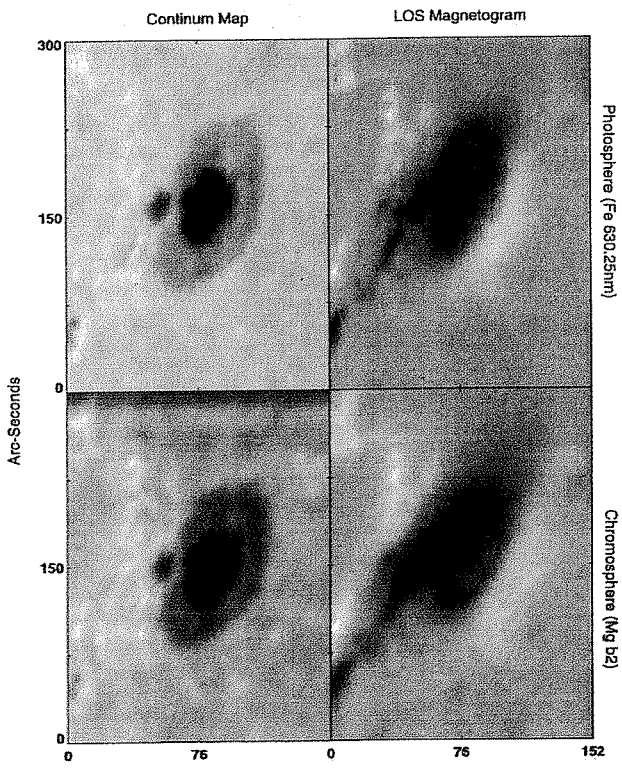


Figure 2.3 Upper Panel: The continuum intensity map (left) and photospheric longitudinal magnetogram (right). Lower Panel: continuum intensity (left) and chromospheric longitudinal magnetogram (right)

nature to photospheric Fe I line observations. Further, the spatial distribution of Stokes-V asymmetry is analyzed using Net Circular Polarization (NCP) maps. The chromospheric and photospheric NCP maps are different in many aspects.

(Sanjay Gosain and Debi Prasad Choudhary)

Helioseismology

Helioseismic Investigation of Sun's Radius with Changing Magnetic Activity

The frequencies of f-modes can be directly used to estimate the solar radius to a good accuracy. In recent years, several efforts have been made to study temporal variations in the solar radius with conflicting results. Using f-mode oscillation frequencies from Michelson Doppler Imager for a period of 7 years, we find that a significant fraction of the f-mode frequency changes with time. If these are interpreted in terms of a radius change, it implies that Sun shrinks during the ascending phase of the solar activity. However, it is to be noted that the shrinkage in the Sun's radius does not refer to the surface radius but, rather, to the layers beneath the visible surface which is known as the seismic radius.

(**S. C. Tripathy**, Kiran Jain and S. S. Hasan)

Characteristic Patterns of Solar Oscillation Frequencies with Activity Indices

The intermediate degree p-mode frequencies measured by GONG and MDI/SOHO for a period of 9 years are used to study characteristic patterns with various solar activity proxies. We find that the indices which measure the solar magnetic activities at photosphere do not show any variations between the ascending and descending phases of the solar cycle. On the other hand, the indices representing magnetic activity above the photosphere exhibit a clear hysteresis pattern by following different paths during the rising and falling phases.

(**S. C. Tripathy** and Kiran Jain)

Solar p-mode Characteristics Associated with the Super-active regions Observed During October-November 2003

Three large active regions, NOAA 10484, 10486 and 10488 dominated the solar disk during October-November 2003. Of these, NOAA10486 was the most flare productive, and was ideally located close to the disk center - suitable for reducing projection effects. NOAA 10486 gave rise to two flares of exceptional magnitude during October 28-29, 2003, which were expected to influence solar p-mode characteristics. We have used local helioseismic technique of ring diagram analysis applied to the Michelson Doppler Imager (MDI) Dynamics Program data from the Solar and Heliospheric Observatory (SOHO). The 3-D power spectra obtained for this active region has been studied in order to find possible flare associated effects on the amplitude, frequency

and width of the p-modes. Although the magnetic index of this active region was comparatively high, flare associated excitation of p-mode power is perceptible for n=0, 1, 2 and 3, as shown in **Fig. 2.4**. This active region also produced the record setting, unprecedented X28 flare of November 4, 2003, however it was not suitable for our study due to the large projection effects, as the active region had reached the W-limb. The two other large, but relatively less flare productive active regions, NOAA10484, and NOAA10488 observed during this period have also been included for comparison with NOAA10486. This work is in collaboration with S. Basu, H.M. Antia and R.S. Bogart

(A. Ambastha)

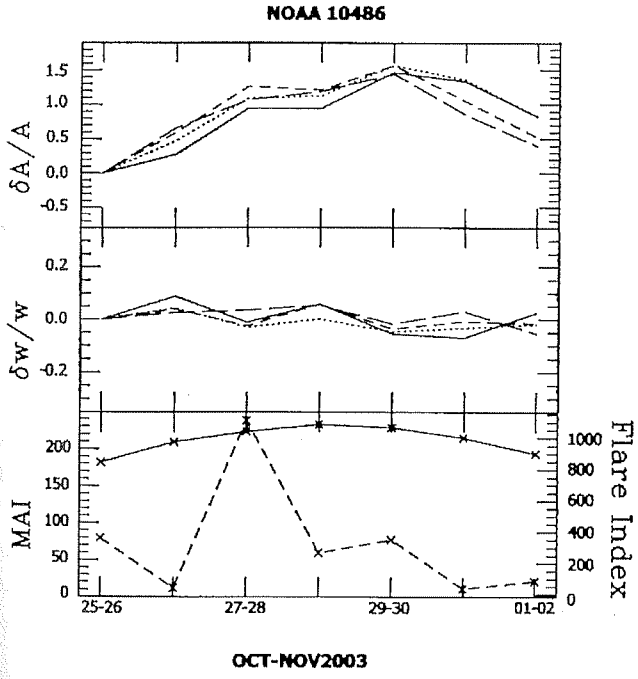


Fig.2.4 The evolution of the magnetic index, MAI, and the flare index, FI, for NOAA10486 is compared with the daily evolution of mode characteristics like amplitude and width of modes. In the lowest panel, the black line shows MAI values, while the red line shows the flare index. In the upper two panels the results are shown for n=0,1,2,3 modes. The amplitude and widths are averaged over all modes in frequency range of 2.5-3mHz for f modes (n=0) and over 3-3.5 mHz for p-modes.

Variations in Low-l Solar p-modes with Disk-averaged, Global, Flare Index

Long time series of helioseismic data has become available from ground-based networks, such as, GONG and space-borne instruments on-board SOHO, using which it has become possible to study temporal change of solar global oscillations. The power of solar p-modes has been found to vary on the time-scales of several days to several weeks, and longer. We have studied the temporal variation of power in low-l modes and compared it with solar disk integrated flare-index. GONG power spectrum data for over 2400 days long time-series obtained in the period of May 1995-December 2001 has been used for our study. Variations in the running mean mode power corresponding to l=0 modes with different radial orders (n=16, 17, ...) are found to be generally stochastic in nature. A comparison of the temporally varying p-mode power with the disk-integrated flare-index does not show any unambiguous correlations.

(**A. Ambastha** and H.M. Antia)

Comparative Study of LiNbO3 and Servo Controlled Air Gap Fabry-Perot Etalons for Solar Applications

We compare the LiNbO3 and Piezo-Electrically (PE) servo controlled air gap Fabry-Perot etalons for observing the Sun. An identical test setup was used to evaluate the instrumental parameters of the two etalons. It is found that for the etalons with similar finesse the advantage of using PE Etalons is tunability over entire Free Spectral Range. On the other hand, the LiNbO3 etalons have advantage of wider acceptance angle.

(Debi Prasad Choudhary and Sanjay Gosain)

Estimation of Fried's Parameter from Long Exposure Solar Images

We propose a criterion for extending the parameter search method of estimating the point spread function to solar data. In the parameter search method, the

number of pixels with negative intensity values in the restored object is used as an estimator for determining the unknown parameters of the point spread function. As a solar image has a high background, restored object does not contain negative values, thereby making the method unsuitable for solar data. We propose to use the intrinsic contrast of solar features as a criterion for identifying the unknown parameter. We validate our method through simulations. This method can not be used for image restoration but can be used for monitoring daytime seeing.

(R. Sridharan, Nirvikar Dashora. and P. Venkatakrishnan)

Submillimeter Science

Theoretical models developed using "RATRAN" computer code, are designed to calculate the radiative transfer and excitation of molecular lines using the Monte Carlo method. The physical model is based on the 1-dimensional inside-out collapse model, where the populations are computed for different molecules at various abundances. Also, we are using the 1-D radiative transfer code, DUSTY, to reproduce the spectral energy distribution and images from continuum images. To validate these models, we are analysing data from few submillimeter observatories using Continuum Line Analysis Single dish Software (CLASS) and using Image Reduction and Analysis Facility (IRAF) software. Development of 1-D codes for radiative transfer modelling is underway.

(Satheesh Thampi, Hemant Dave, Ashish Dubey, R. P. Singh and Vinay Kumar)

SMM Technology

Local Oscillator Development

Laboratory local oscillator is calibrated and characterized for CH_3 OH 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.

(Hemant Dave, R. P. Singh, Vinay Kumar, Ashish Dubey, Satheesh Thampi, and Jayesh Pabari)

Development of innovative LO cavity structure with special coupling scheme for FIR output is in progress. Design of this innovative coupler is based on the unequally spaced slot array over the broad wall of cavity. For optimizing the slot spacing and mutual coupling between slots, we have simulated various configurations of propagating structures with different slot locations. In case of randomly spaced slots, maximum intensity has been observed with better directivity. Presently, we are applying the same theory to overmoded waveguide at 700 GHz. For this, we considered WR-10 waveguides, which are suitable for 90-140 GHz in real size theory. **Fig. 3.1** shows the simulated far field intensity pattern of main lobe for all cases. Red colour represents the intensity profile for the random location of slots, which is significantly narrow with maximum intensity.

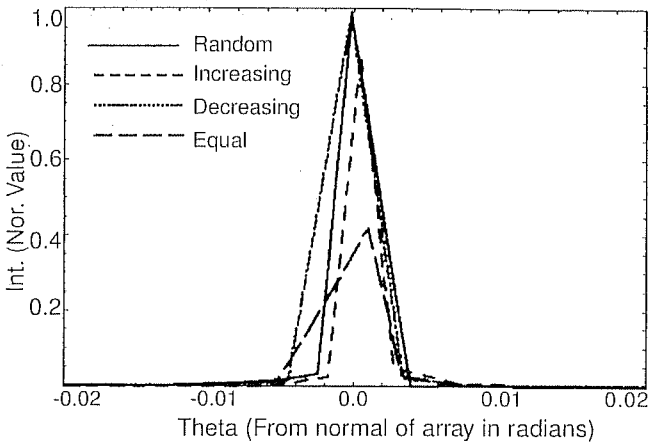


Fig. 3.1 : Simulated far field intensity profile of main lobe for all cases

(Ashish Dubey and Hemant Dave)

Detector Development

We are acquiring a series of diode detectors to cover the entire SMM region, i.e. 300-3000 GHz for the laboratory characterization of space payloads. The noise temperature measurement for the room temperature detector system is underway.

(Hemant Dave, Ashish Dubey, R. P. Singh, N. M. Vadher, Jayesh Pabari and Satheesh Thampi)

Back End Electronics

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 600 MHz and frequency resolution 40 kHz. It is based on the Chirp transformation technique used to get frequency spectrum of unknown CW signal. Phase spectrum of the signal may not be required in astronomi-

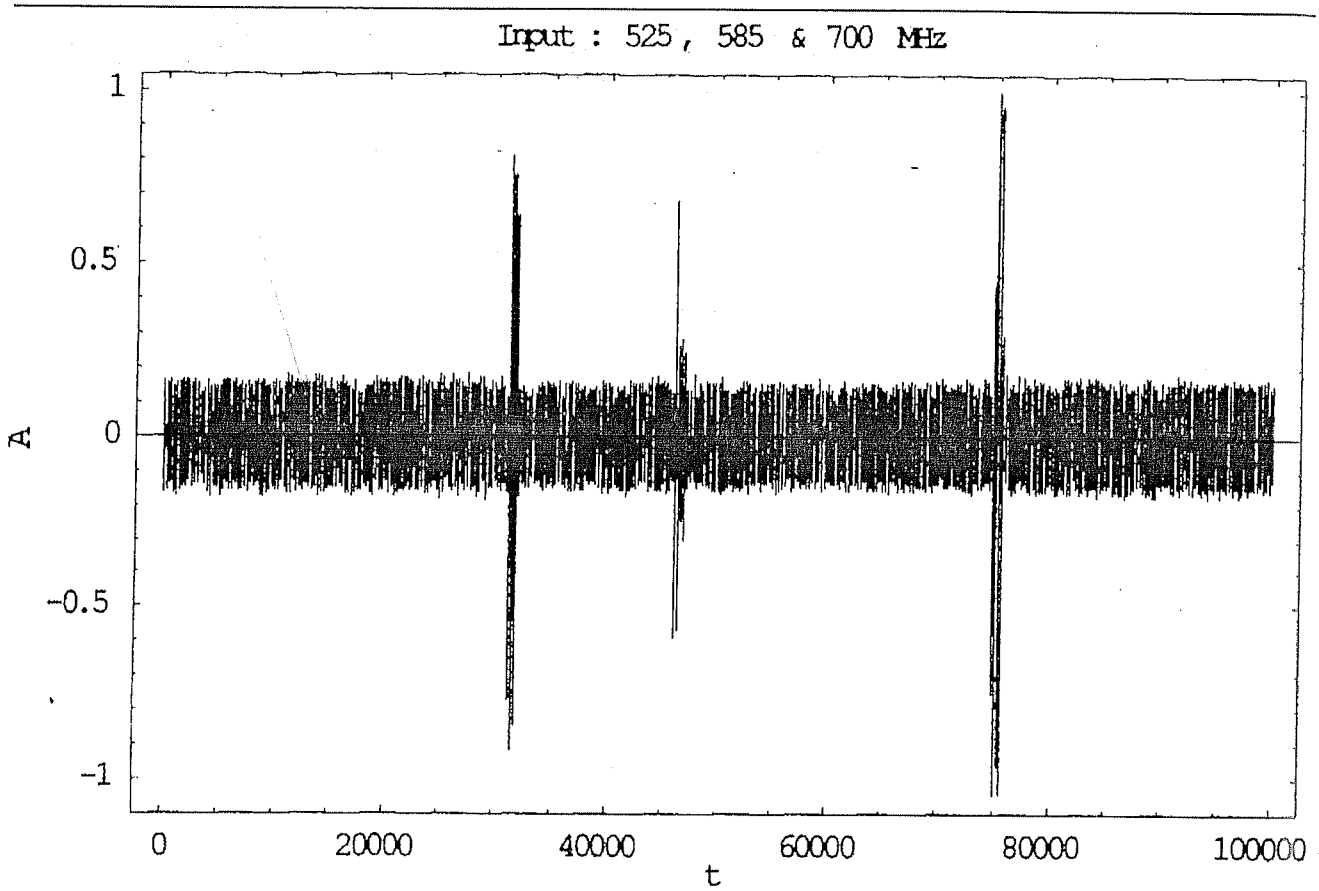


Fig. 3.2 : Separation of frequency components of input signal using Chirp processor

cal observations and can be omitted. Performance of Chirp processor has been verified by simulations. **Fig. 3.2** shows how the frequency components present in input signal can be separated using Chirp processor. Design parameters of state-of-the-art Surface Acoustic Wave (SAW) devices for CTS have been initialized and fabrication process of the devices is underway. The chirp filters are Reflective Array Compressor (RAC) type SAW filters providing very high time bandwidth product. **Fig. 3.3** shows the impulse response of surface acoustic wave (SAW) chirp filter. The negative chirp signal required for the spectrometer is actively generated using programmable chirp synthesizer. The testing of subsystems of CTS have been started.

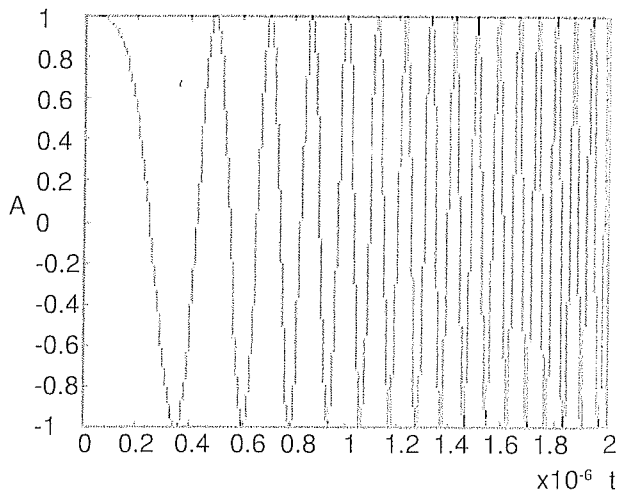


Fig. 3.3 : The impulse response of surface acoustic wave (SAW) chirp filter.

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

Results of Observations of Solar Flares made by Solar X-ray Spectrometer (SOXS) Mission

The first space borne solar astronomy experiment of India namely "Solar X-ray Spectrometer" (SOXS) mission has completed one year of its successful operation in geostationary orbit. The SOXS mission onboard GSAT-2 Indian spacecraft was launched successfully by GSLV-D2 rocket on 08 May 2003 to study the energy release and particle acceleration in solar flares. The SOXS is composed of two independent payloads viz. SOXS Low Energy Detector (SLD) payload, and SOXS High Energy Detector (SHD) payload. SLD payload was designed, developed and fabricated by Physical Research Laboratory (PRL) in collaboration with Space Applications Centre (SAC), Ahmedabad and ISRO Satellite Centre (ISAC), Bangalore of Indian Space Research Organization (ISRO). The SLD payload employs the state-of-the-art solid state detectors, viz., Si PIN and Cadmium-Zinc-Telluride (CZT) devices that operate at near room temperature (-200 C). The dynamic energy ranges of Si PIN and CZT detectors are 4-25 and 4-56 keV. The Si PIN provides sub-keV energy resolution while CZT reveals ~2 keV energy resolution throughout the dynamic range. The instrument has onboard flare triggering logic software and 5 MB-memory bank. The data is transmitted to Master Control Facility (MCF), Hasan with 8 kbps telemetry rate. The observations are made in fixed energy windows (temporal) mode and in spectral mode with 100ms cadence during the flare.

The SLD has observed more than 180 flares of C and M class since its commissioning in the orbit. **Figs. 3.4 & 3.5** show the light curves of the solar flare observed on 06 January 2004 by Si and CZT detectors. It may be noted that both the detectors show unambigu-

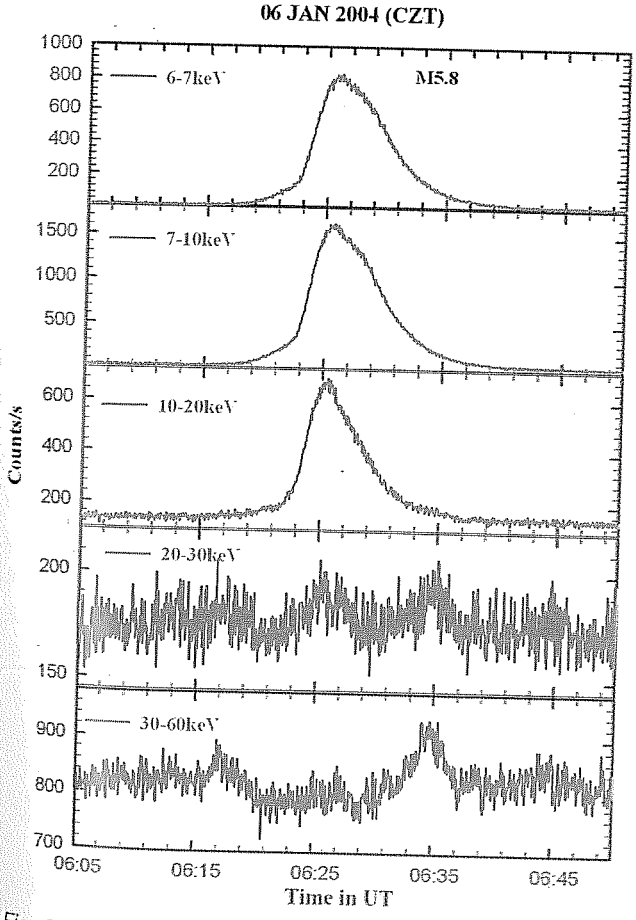


Fig. 3.4 : Light curve of solar flare observed by CZT detector on 06 Jan 2004

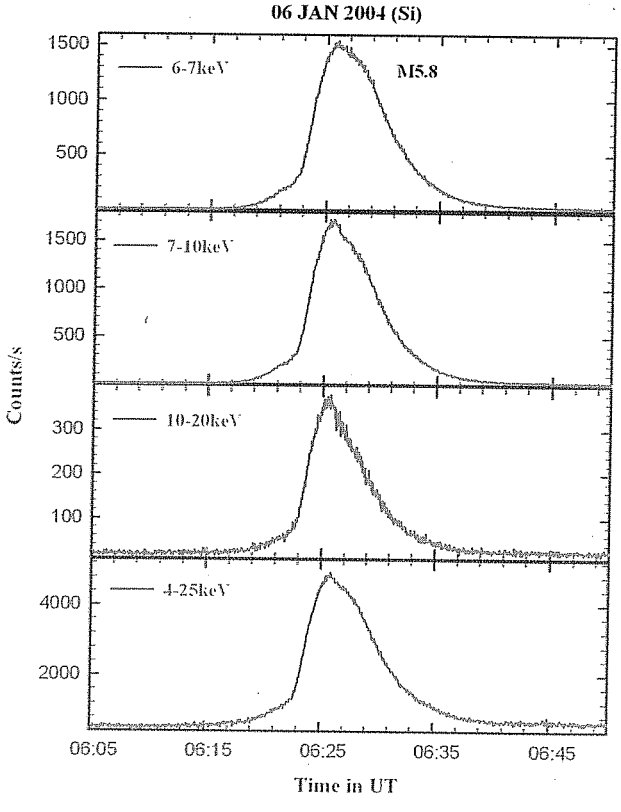


Fig. 3.5 : Light curve of solar flare observed by Si detector on 06 Jan 2004

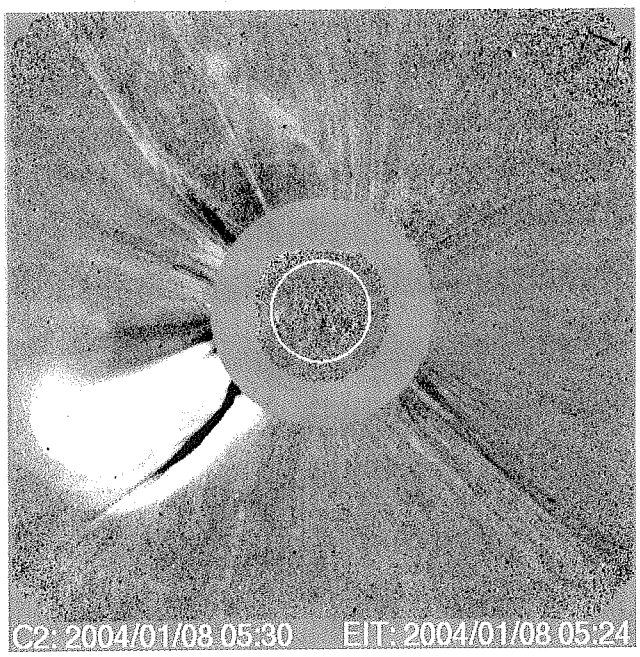


Fig. 3.6 : CME observed by EIT/SOHO on 08 Jan 2004

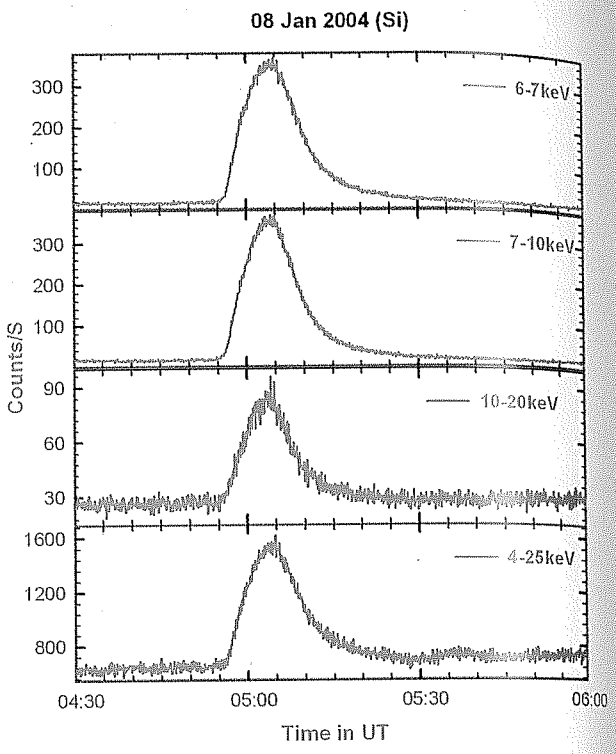


Fig. 3.7 : Light curve of solar flare observed by SOXS on 08 Jan 2004

ously the iron line complex at 6.7 keV, while Si detector also shows a shoulder of iron-nickel line complex at 8 keV. The high sensitivity of the SLD and sub-keV energy resolution of Si PIN detector allow the intensity and mean energy of the Fe-line complex at approximately 6.7 keV to be measured as a function of time in all class of flares. The centroid energy and width of the iron-line complex at ~6.7 keV, the intensity of the Fe/Ni line complex at ~8 keV, and the line-to-continuum ratio enabled to estimate the plasma temperature and other plasma parameters.

(Rajmal Jain, Hemant Dave, Sumit Kumar and M. R. Deshpande)

Impulsive Solar Flares Associated with Coronal Mass Ejections

Analysis of observations of unusual phenomena of impulsive flares that associated with coronal mass ejections is undertaken. We are analyzing multi-wavelength observations of a few impulsive solar flares, which are associated with Coronal Mass Ejections (CMEs) during Solar Cycle 23, in great detail. The optical and radio waveband observations of the solar flares considered for this investigation were made in India and Japan, while SOHO, CGRO, YOHKOH and SOXS missions made the other wavelength observations. The optical, radio and X-ray emission characteristics of these impulsive flares associated with CMEs are studied in view of their energy release and particle acceleration. We conjecture a model to interpret our multi-spectral observations of these impulsive solar flares. It is proposed that a CME of some magnitude precedes the impulsive solar flares to cause strong particle acceleration as observed in them. In support of our concept we present the magnetograms of the active regions that reveal the cancellation of magnetic flux in all such impulsive events, which in turn, results in generating a CME as seen in different wavelengths. Shown in **Fig. 3.6** is a CME observed by SOHO on 08 January 2004, which triggered the solar flare that observed by SOXS as shown in **Fig. 3.7** (right).

(**Rajmal Jain**, Wahab Uddin, Takeo Kosugi, Sumit Kumar, Ramesh Chandra, Taro Sakao, Satoshi Masuda and Lokesh Bharti)

Astrophysics

Mass Radius Relation for Compact Stars: Constraints due to Lensing Effect

During the last couple of years, astronomers and astrophysicists have been debating on the fact whether the so called 'strange stars' – stars made up of strange quark matter, have been discovered with the candidates like SAX J1808.4-3658, 4U 1728-34, RX J1856.5-3754, etc. The main contention has been the estimation of radius of the star for an assumed mass of ~$1.4M_{\odot}$ and to see whether the point overlaps with the graphs for the neutron star equation of state or whether it goes to the region of stars made of strange matter equation of state. Using the well established formulae from general relativity for the gravitational redshift and the 'lensing effect' due to bending of photon trajectories, the parameters M and R are related with the observable parameters, the redshift z and the radiation radius R_{∞}, thus constraining both M and R for specific ranges, without any other arbitrariness. With the required inputs from observations, one ought to incorporate the effects of self lensing of the compact stars which has been otherwise ignored in all of the estimations done so far. Nonetheless, these effect of self lensing makes a marked difference and constraints on the M-R relation.

(**A.R. Prasanna** and Subharti Ray)

Analysis of Accretion Flows around Rotating Compact Objects including Coriolis Effect: A Fluid Dynamics Based Approach

We study the kinematics of fluid flows which forms a geometrically thin disk around compact objects, in a pseudo-Newtonian approach. The effect of rotation to the central object is included through the Coriolis acceleration term into the fluid equation. The introduction of the Coriolis term into the fluid equation renders a change in the effective angular momentum of the fluid and affects the known parameter space of the non-rotating system. Further, the possibility of shock wave formation in fluid is reduced and several parameter regions which were thought to be stable are shown not to be so even for low values of angular momentum of the compact object.

(**A.R. Prasanna** and B. Mukhopadhyay)

Gauge Invariant Wave Equations in Curved Space-Times and Primordial Magnetic Fields

Considering a non-minimal coupling of the electromagnetic field with gravitational field, through a curvature, field tensor coupling of the form $\lambda R_{\alpha\beta\gamma\delta}F^{\alpha\beta}F^{\gamma\delta}$, for the Lagrangian, we derive a new set of wave equations for the electromagnetic fields, which are gauge invariant, but break conformal invariance. This fact now helps in creating a scenario as proposed by Turner and Widrow for the production of seed magnetic field at the early Universe, which can meet the requirements for the existence of primordial magnetic field, developing into the presently observed galactic magnetic field. In fact the main source of amplification, comes from the non-minimal coupling term, which accentuates the growth of the field during the reheating phase of the Universe.

(**A.R. Prasanna** and G. Lambiase)

Rotating Cylindrical Collapse: An Example

We investigate a case of rotating collapse with cylindrical symmetry. We find that singularities form from regular initial data. They are naked or covered depending on initial rotation which we define. We show this by investigating radial null as well as spiral timelike geodesics. Rotation appears to uncover the singularity formed. Three cases are studied depending upon various pressures assumed to be zero (axial, radial and azimuthal), one at a time. The three cases together bring out the role of pressure in covering the singularity formed, over and above the role of rotation.

(S. Barve, S. Jhingan and A.R. Prasanna)

Atomic and Molecular Physics

Accurate Quantum Expressions for Radiative Transitions between Nearby Rydberg States

For the quantum mechanical study of radiative transitions between nearby Rydberg states, the following 3

main results have been derived. (1) An accurate quantum expression of the radial matrix element for radiative dipole transition between nearby Rydberg states. Its remarkable numerical accuracy is demonstrated over a very wide range of the principal and orbital angular momentum quantum numbers covering low-lying states to very high Rydberg states, (2) A simple but accurate approximation to a class of terminating hypergeometric functions whose 3 arguments are large. This result essentially solves the problem of extracting analytic properties and performing numerical computation of such hypergeometric functions over a large range of values of the arguments which had earlier defied solutions, (3) A derivation of the formula of the radial dipole matrix element of the correspondence principle method starting from the corresponding quantum expression, which, to the best of our knowledge, was not previously available in the literature.

(D.P. Dewangan)

A Complete Solution of the First Born Amplitude for $n_i s \rightarrow n_f s$ Transition on the Hydrogenic Bound-states

We have obtained a complete solution of the first Born amplitude for $n_i s \rightarrow n_f s$ transition covering the entire set $(n_i, n_f = [1, \infty)$ of the hydrogenic bound-states. An exact compact expression of the $n_i s$ - $n_f s$ first Born amplitude in terms of only one Jacobi polynomial is derived that serves as a basis for obtaining simple compact quantum expressions for a variety of cases which include elastic scattering, transition between adjacent Rydberg states, distant Rydberg states, transition connecting any low lying s-state to a very high Rydberg state. A general quantum formula for transition between nearby Rydberg states is also derived, of which, the expressions of the correspondence principle method previously reported in the literature are specific examples. All the formulae are derived using quantum mechanics without making any appeal to classical mechanics even for states lying in the vicinity of the limiting point $n_i, n_f \rightarrow \infty$ of the hydrogenic bound energy levels.

(D.P. Dewangan)

Permanent Electric Dipole Moments of Closed-shell Atoms

The observation of a finite intrinsic electric dipole moment (EDM) of a particle or a composite system is a signature of parity (P) and time (T) reversal violations. Neutral atoms are good candidates to probe for P and T violations in lepton, hadronic and semi-leptonic sectors. The experimental data after combining with atomic theory calculations provide bounds on parameters of non-standard model and are probes for physics beyond the standard model of the particle physics. We are developing a coupled cluster based method to calculate the EDM of closed-shell atoms. Our implementation is oriented towards the calculation of Hg EDM arising from tensor-pseudotensor electron-nucleus interaction and Schiff moment. Accurate atomic theory calculations of Hg EDM shall compliment the experimental results of unprecedented accuracy and provide inputs to extract finer bounds on several theoretical parameters. The results obtained is expected to provide an understanding of the P and T violating effects arising from nucleon-nucleon and electron-nucleon interactions. It is to be noted that coupled-cluster method is considered the most accurate theoretical many-body method. However, the use of coupled-cluster method for properties calculation of heavy atoms like Hg poses difficult challenges in atomic theory and efficient computational implementation.

(**Dilip Angom**, K. V. P. Latha and B. P. Das)

Changing Nature of Complexities in Rare Earth Atoms

The rare earth atoms have partially filled high angular momentum 4 *f* and 5*d* valence shells. This leads to complex configuration mixing and hence, the rare earth atoms are appropriate system to study the role of two-body interaction in producing chaos. Across the period there is an increase in the occupancy of 4 *f* and accordingly we observed a change in the statistical properties of the eigenvalues and eigenfunctions. Among the rare earth elements, we are studying Nd, Pm and Sm in detail, this adds to the existing work on Ce and Pr. We find

energy dependent variation in the shape of the strength function for all the atoms, this was also observed in previous works on Ce and Pr. All the atoms have localized states. This is evident from the number of principal components and localization length calculations. The occupation number studies show the localized states correlate with the occupancies of specific sub-shells. To investigate the variations in the properties among the atoms and gain an understanding of the random matrix ensemble in operation, we are currently studying the structure of the Hamiltonian matrices.

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

High Energy Physics

Neutrino Mass Textures from Symmetry Principal

Development of proper theoretical model for understanding neutrino oscillation results is one of the important problems in particle physics. One ad hoc procedure followed is to consider leptonic mass matrices with zero entries at various places in order to reduce the number of parameters. It was shown that it is always possible to find discrete Abelian symmetries which can reproduce any desired texture zeros for the fermion masses. This method works not only for neutrinos, but also for other fermions and in the standard model as well as in grand unified theories.

(**A.S. Joshipura**, W. Grimus, L. Lavoura and M. Tanimoto)

Broken Z_2 and Induced U_{e3} and Cos $2\theta_{23}$

The neutrino mixing matrix U as determined from the available information on neutrino oscillations contain two small parameters, namely U_{e3} and Cos $2\theta_{23}$, where θ_{23} is the atmospheric neutrino mixing angle. This feature can be understood from a Z_2 flavour symmetry. We systematically considered breaking of this symmetry and made detailed quantitative estimates for the magnitudes of U_{e3} and Cos $2\theta_{23}$. These predictions can be tested in future experiments which are designed to look for these parameters.

(**A.S. Joshipura**, W. Grimus, S. Kaneko, L. Lavoura and M. Tanimoto)

Long Range Forces and Long Baseline Experiments

The study of long range fifth force much weaker than the gravitational interactions has attracted a lot of attention. It was shown that neutrino oscillations can provide a very sensitive tool to study such forces provided they distinguish between leptonic flavours. The atmospheric neutrino results were analyzed in detail to obtain constraint on such forces. These constraints are much stronger than the laboratory limits from the fifth force experiments. But they still allow such forces to manifest themselves in future long baseline experiments, which will study oscillations of neutrinos traveling several hundred kilometers from their sources. This investigation formed a part of the joint working group activities of the "APS multi-divisional study of the physics of neutrinos."

(A.S. Joshipura and S. Mohanty)

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

We consider the linear sigma model at finite temperature and finite baryon density using a variational approach. The method essentially uses the ansatz of a squeezed coherent state in field theory and is self-consistent. The gap equations for sigma and pion masses are self consistently calculated solving the corresponding gap equations. The phase diagram of the model is also constructed. Depending on the strength of the coupling to the quarks, the transition could be first order or second order.

(**H. Mishra** and Amruta Mishra)

Gapless Modes in Color Superconductivity and Cooling of Neutron Stars

Gapless modes in color superconductivity can occur for quark matter at finite baryon densities when charge neutrality condition is imposed leading to a mismatch in fermi momenta of the condensing quarks. Using the variational method considered recently we calculate the temperature effects on the gap and the gapless modes as may be relevant for neutron stars. We also

calculate explicitly the cooling rate of neutron stars by neutrino emission from color superconducting matter. Relevance of temperature dependence and the gapless modes is also examined.

(**H. Mishra**, A. Mishra, P. Jaikumar and Charles Gale)

Color Flavor Locking and Gapless Modes in Neutral Dense Matter

We consider the phase diagram for 3 flavor quark matter. At sufficiently high density when the strange quark mass is unimportant, the matter is supposed to be in color flavor locked state in which the strange quark also participates in condensation alongwith the ud quarks. However, at smaller densities it is likely that a gapless color flavor locked phase will be dynamically favorable resulting because of a mismatch in fermi momenta of the quarks arising from a difference in masses. The free energy of this state is also compared to gapless superconducting phase where only the light quarks take part in condensation. The phase diagram is calculated in a 3 flavor Nambu Jona-Lasinio model. Implications of the results on neutron star properties are also discussed.

(**H. Mishra** and A. Mishra)

Gapeless Modes in Colour Superconductivity

We investigated the vacuum realignment for chiral symmetry breaking and color superconductivity for finite density quark matter in a Nambu Jona-Lasinio model using a variational method. The treatment allows us to investigate simultaneous formation of condensates in quark-antiquark as well as in diquark channels. The methodology involves an explicit construction of a variational ground state and minimization of the thermodynamic potential. Color and electric charge neutrality conditions are imposed through introduction of appropriate chemical potentials. Color and flavor dependent condensate functions are determined through functional minimization of the thermodynamic potential. The equation of state for charge neutral color neutral color superconducting quark matter is calculated. Simultaneous existence of a mass gap and superconducting gap is seen in a small window of the quark chemical potential. Enforcing color and electric charge neutrality condition leads to existence of gapless superconducting modes depending upon the magnitude of the gap and the difference of the chemical potential of the condensing quarks.

(**H. Mishra** and A. Mishra)

Gapeless Modes in Cold Atoms

A new superfluid phase in Fermi matter, termed as "interior gap" and breached pair has been recently predicted. This results from pairing between fermions of two species having essentially different fermi surfaces. We use a variational method to analyze the features as energy gap, momentum distributions and elementary excitations associated with the predicted phase. The variational state is more general than that suggested by Liu and Wilczek. We also discuss possible realization of such breached paring phase in two component fermi gases in an optical trap.

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

Implications of Neutrinoless Double Beta Decay

One of the most important characteristics of the neutrinos is that they could be Majorana particles. Then their masses will violate lepton number. Thus any evidence of Majorana masses of the neutrinos will be the first evidence for lepton number violation in nature. The neutrinoless double beta decay experiment is the only experiment planned till now which can detect Majorana masses of the neutrinos. Recently a positive evidence of neutrinoless double decay has been announced. The consequences and implications of this evidence for other lepton number violating interactions in nature have been analyzed.

(**Utpal Sarkar** and H.V. Klapdor-Kleingrothaus)

Gauged [B - 3 L(tau)] and Proton Decay

Baryon and lepton numbers are global symmetries of the standard model of electroweak interaction, which is broken through quantum corrections. There are some proposals for considering extensions of the standard model, in which some combinations of baryon and lepton numbers are local symmetries. We studied the pos-

sibility of gauging the B - 3 L(tau), where L(tau) is the tau lepton number. We point out that proton is stable in this model. This helps in building unified models of TeV scale and large extra dimensions. This also allows us to construct R-parity violating supersymmetric models, in which lepton number is broken preventing fast proton decay naturally. Even after the symmetry breaking proton remains stable in all the models with gauged B - 3 L(tau).

(**Utpal Sarkar** and P.B. Pal)

CP Violation at a Linear Collider with Transverse Polarization

It is shown how transverse beam polarization at e^+e^- colliders can provide a novel means to search for CP violation by observing the distribution of a single final-stage particle without measuring its spin. An azimuthal asymmetry is suggested which singles out interference terms between standard model contribution and new-physics scalar or tensor effective interactions in the limit in which the electron mass is neglected. Such terms are inaccessible with unpolarized or longitudinally polarized beams. The asymmetry is sensitive to CP violation when the transverse polarizations of the electron and positron are in opposite senses. The sensitivity of planned future linear colliders to new-physics CP violation in $e^+e^- \to t\bar{t}$ is estimated in a model-independent parameterization. It would be possible to put a bound of ~ 7 TeV on the new-physics scale λ at the 90% C.L. for centre of mass energy of 500 GeV and integrated luminosity of 500 fb^{-1}, with transverse polarizations of 80% and 60% for the electron and positron beams, respectively.

(**S.D. Rindani** and B. Ananthanarayan)

Transverse Beam Polarization and CP-violating Triple-gauge-boson Couplings in $e^+e^- \to \gamma Z$

Anomalous CP-violating $\gamma\gamma Z$ vertex can give rise to a novel asymmetry in the presence of transversely polarized electron and positron beams in the process $e^+e^- \to \gamma Z$. This asymmetry, which is odd under naive time reversal, is proportional to the real part of the $\gamma\gamma Z$ CP-violating coupling. This is in contrast to the simple forward-backward asymmetry of the γ (or Z) in the presence of unpolarized or longitudinally polarized beams studied earlier, which is even under naive time reversal, and is proportional to the imaginary part. The sensitivity of future experiments to the determination of CP-odd $\gamma\gamma Z$ and γZZ couplings using transversely polarized beams has been investigated.

(**S.D. Rindani**, B. Ananthanarayan and R.K. Singh)

Kinetic Equation for Electroweak Baryogenesis- I

The kinetic equation for fermions and antifermions interacting with a planar Higgs bubble wall during the electroweak phase transition using the 'evenisation' procedure has been derived. Equations of motion in a relativistic quantum theory do not mirror classical relations unless one uses evenised operators. The evenised Heisenberg equations of motion have been used to obtain the velocity and force for the particles in the presence of the Higgs bubble wall. The Higgs interaction with particles is described by a complex fermion mass. Keeping quantum contributions to O(h) in the equations of motion, the semi-classical force obtained earlier by other field theoretic techniques have been derived.

(J. R. Bhatt and R. Rangarajan)

Kinetic Equation for Electroweak Baryogenesis-II

To understand better certain issues associated with the identification of the canonical and kinetic momentum for fermions interacting with a Higgs bubble wall during the electroweak phase transition, the phase of the complex fermion mass was rotated and considered a Lagrangian with a real fermion mass and an extra term in the momentum operator. The energy, velocity and force for the fermions using the evenisation approach and the Wigner formalism was obtained and found that our results using both methods agree. Furthermore, it appears that the ambiguity related to the identification of the canonical and kinetic momentum may not be present in

this case. The issues related to identifying the particle distribution function in the Wigner formalism was also discussed.

(J. R. Bhatt and R. Rangarajan)

Constraints on Electromagnetic Form Factors of Neutrinos from Beta Decay Experiments

Neutrinos with non-zero dipole or anapole moments have a non-zero effective mass in the electromagnetic field of nuclei. This effective mass can be probed in beta decay experiments which provide constraints on the neutrinos electromagnetic form factors.

(**S. Mohanty**, Fred Myhrer and K.Kubodera)

Neutrino Oscillations in the Presence of Long Range Forces

A combined analysis of solar, atmospheric and terrestrial neutrino experiments assuming the presence of new long-range forces was carried out. The standard pattern of neutrino masses and mixings can change substantially in the presence of such long-range forces.

(A. Joshipura and S.Mohanty)

Leptogenesis by Cosmological Gravitational Waves

Inflationary theories predict the existence of a background density of gravitational waves. These gravitational waves split the energy levels of neutrinos and anti-neutrinos. This can give rise to a lepton number asymmetry at equilibrium in the early universe of the magnitude required by big-bang nucleosynthesis.

(S.Mohanty and A.R.Prasanna)

Nuclear Physics

Random Interactions in Nuclei and Extension of 0+ Dominance in Ground States to Irreps of Group Symmetries

Random one plus two-body hamiltonians invariant with respect to $O(N_1) \oplus O(N_2)$ symmetry in the group-subgroup chains $U(N) \supset U(N_1) \oplus U(N_2) \supset O(N_1) \oplus O(N_2)$ and $U(N) \supset O(N) \supset O(N_1) \oplus O(N_2)$ of a variety of interacting boson models of atomic nuclei are used to investigate the probability of occurrence of a given $(\omega_1 \omega_2)$ irreducible representation (irrep) to be the ground state in even-even nuclei; $[\omega_1]$and $[\omega_2]$ are symmetric irreps of $O(N_1)$ and $O(N_2)$ respectively. Employing a 500 member random matrix ensemble for N boson systems (with N = 10 – 25), it is found that for $N_1, N_2 \geq 3$ the $(\omega_1 \omega_2) = (00)$ irrep occurs with ~ 50% and $(\omega_1 \omega_2) =$ (N0) and (0N) irreps each with ~ 25% probability. Similarly, for $N_1 \geq 3$, $N_2 = 1$, for even N the $\omega_1 = 0$ occurs with ~ 75% and $\omega_1 = N$ with ~25% probability and for odd N, $\omega_1 = 0$ occurs with ~50% and $\omega_1 = 1, N$ each with 25% probability. An extended Hartree-Bose mean-field theory is developed to explain all these results. In this study, for the first time TBRE's preserving irreps of group symmetries (other than O(3)), for boson systems, are introduced. Extensions of the present study will give deeper understanding of geometric chaos and regularities generated by random interactions in finite quantum systems and work in this direction is in progress.

(V.K.B. Kota)

Number of Principal Components and Localization Length in E2 and M1 Transition Strengths in ^{46}V

Predictions of the embedded Gaussian orthogonal random matrix ensemble of one plus two-body interactions [EGOE(1+2)] (given by PRL scientists in 1998), in the Gaussian domain, for the number of principal components and localization length, measuring complexity and chaos in transition strengths originating from an eigen-state with energy E, are tested successfully for the first time for electric quadrupole (E2) and magnetic dipole (M1) transition strengths. Shell model results for the 2p1 f-shell nucleus ^{46}V are used as the example. Considered here are E2 isoscalar transitions from the initial space of 814 $J = 0^+, T = 0$ levels to the final space of 3683 $J = 2^+, T = 0$ levels and to the 4105 $J = 1^+, T = 0$ levels for the isovector M1.

(**V.K.B. Kota**, J.M.G. Gómez, J. Retamosa and K. Kar)

Shell Model Group-subgroup Chains Complementary to the Group Chains of the O(8) Pairing Model

Isoscalar* (T=0) plus isovector (T=1) pairing hamiltonian in LS-coupling, which is important for heavy N = Z nuclei, is solvable in terms of a O(8) algebra for some special values of the mixing parameters that measures the competition between T = 0 and T = 1 pairing. The O(8) algebra is generated, amongst others, by the T = 0 and T = 1 pair creation and annihilation operators. Shell model algebras (group-subgroup chains), with only number conserving operators, that are complementary to the O(8) $\supset$ O(6) and O(8) $\supset$ O(5) $\otimes$ SU(2) sub-algebras with SU(2) in spin or isospin space are identified. An example is $U(4\Omega) \supset [U(2\Omega) \supset Sp(2\Omega) \supset \{[O\Omega) \supset O_L(3)] \otimes SU_T(2)\}] \otimes SU_S(2)$, where Ω is number of spatial degrees of freedom and 4 is the number spin-isospin degrees of freedom of a single nucleon. Some details (generators, Casimir operators and all the quantum numbers for the O(8) seniority v = 0 states) of these shell model group-subgroup chains are worked-out.

(V.K.B. Kota)

Deformed Shell Model for T = 0, 1 and 2L levels in ^{48}Cr

Deformed configuration mixing shell model based on Hartree-Fock states with extension to include isospin projection (DSMT) for four quasiparticle configurations is developed using some properties of the symmetric group S_4. This goes beyond the simple case of isospin (T) projection from two quasiparticle configurations employed in the studies of some heavy odd-odd nuclei reported in the last 2 years. The DSMT model with 2 and 4 particle T projection is used to study the structure of the low-lying T = 0,1 and 2 bands/levels in the even-even N = Z nucleus ^{48}Cr. The pf-shell KB3 interaction is employed in the calculations. The agreement between DSMT and experiment is good. This analysis is being extended to ^{52}Fe and ^{72}Kr.

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

Strength Functions, Entropies and Duality in Weakly to Strongly Interacting Fermion Systems

For weakly interacting fermions in a mean-field with random two-body interactions of increasing strength λ, the strength functions $F_k(E)$ are well known to change, in the regime where level fluctuations follow Wigner's surmise, from Breit-Wigner to Gaussian form. We have proposed an ansatz for the function describing this transition and this is used to investigate the participation ratio ξ_2 and the information entropy S^{info} during this crossover, thereby extending the known behavior valid in the Gaussian domain into much of the Breit-Wigner domain. We have also derived a scaling law for the duality point $\lambda = \lambda_d$, where $F_k(E)$, ξ_2 and S^{info} in both the weak ($\lambda = 0$) and strong mixing ($\lambda = \infty$) basis coincide. As a first realistic application, the ansatz function for strength functions is used in describing the Breit-Wigner to Gaussian transition seen in neutral atoms Cel to Sml with valence electrons changing from 4 to 8 (**Fig. 4.1**). The calculations are carried out using the multi-configuration Dirac-Fock method with single and double excitations from a reference configuration included and the Hamiltonian matrix dimensions varying from 373 to 7325.

(D. Angom, S. Ghosh and V.K.B. Kota)

Strength Functions for Interacting Bosons in a Mean-field with Random Two-body Interactions

Strength functions have been studied numerically for dense interacting boson systems using a Hamiltonian H, which is a sum of a mean-field one-body H1 and a random two-body interaction H2 with strength λ (for this system, last year we reported numerical results for Poisson to GOE transition in level fluctuations, entropy and some aspects of ergodicity). The strength functions, defined with respect to H1 basis, are seen to change gradually from Breit-Wigner to Gaussian form in the chaotic domain as λ increases. A simple function interpolating these two forms is used to describe the intermediate region and a prescription given 3 years back by PRL scientists is then employed to determine λ_F that marks the transition to Gaussian form. Going further, the interpolating form for the strength Function is used to study,

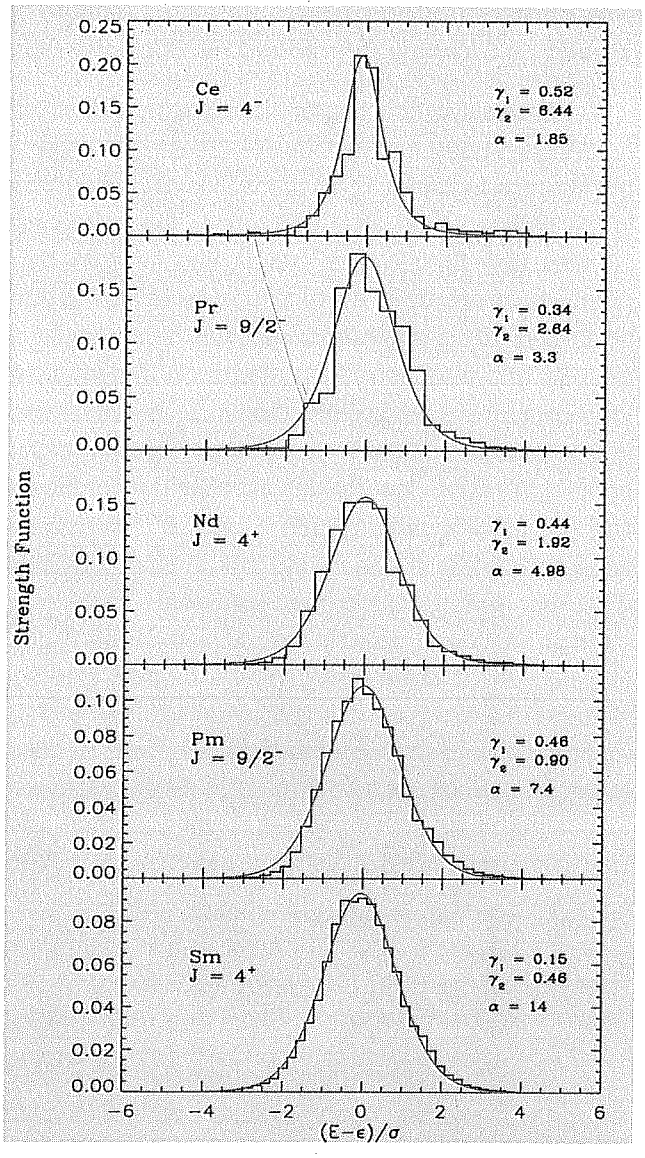


Fig. 4.1 : Strength functions F(E), for the basis states around the center for CeI to SmI with histograms giving calculated strength functions. The continuous curves in the figures are the best fit Bw to Gaussian interpolating function constructed by PRL scientists. The values of the parameter α of this function are shown in the figures. Also given in the figures are γ_1(Skewness) and γ_2 (excess) values. Note that ε and σ are the spectral centroids and widths. Note the close correspondence between EGOE(1+2) and the realistic CeI to SmI results.

in the chaotic domain, variation of occupancy of single particle states with excitation energy E.

(**V.K.B. Kota** and V. Potbhare)

Long-range Interactions in the Quantum Many-body Problem in One Dimension

Ground state properties of a family of N-body systems in one dimension, trapped in a polynomial potential and having long-range two-body interaction in addition to the inverse square potential studied in the Calogero-Sutherland model (CSM), are investigated. It is shown that for such a Hamiltonian the ground state energy is similar to that of free fermions in a harmonic well with a displacement that depends on the number of particles and depth of the well. The ground state wavefunctions have been obtained and using random matrix results, the particle density and pair correlation function (PCF) are studied. It is observed that the particles are arranged in bands and, due to long-range interactions, the PCF shows departures from the CSM.

(S. Ghosh)

Plasma Physics

Dusty Plasma : Surface Phenomena in Complex Plasma

Recently there has been a great deal of interest in investigating properties of a strongly interacting complex (dusty) plasma. One of the interesting aspect of the complex plasma is that under certain condition the plasma can have a free surface. In the presence of ion streaming or shadow force, it can have plasma surface tension. We study dynamical behaviour of the free surface using generalized hydrodynamics wave motions supported by the free surface in a complex plasma. We believe that this is the first study of its kind in complex plasma literature.

(**J.R. Bhatt** and A. Shaikh)

Non-Linear dynamics and complex systems

Coupled Maps on Networks

Self-organized and driven synchronization in coupled map networks for some simple networks, namely two and three node networks and their natural generalization to globally coupled and complete bipartite networks have been studied. Both linear stability analysis and Lyapunov function approach have been used for this study and stability conditions for synchronization have been determined. It is seen that most of the features of coupled dynamics of small networks with two or three nodes, are carried over to the larger networks of the same type. The phase diagrams for the networks studied here have features very similar to the different kinds of networks studied earlier. The analysis of the dynamics of the difference variables corresponding to any two nodes shows that when the two nodes are in driven synchronization, all the coupling terms cancel out whereas when they are in self-organized synchronization, the direct coupling term between the two nodes adds an extra decay term while the other couplings cancel out.

(R. E. Amritkar and S. Jalan)

Coupled Three Dimensional Quartic Oscillator

The low-lying states of the coupled 3-D quartic oscillator where the coupling strength α of each pair of degrees of freedom is the same have been studied. These studies have provided insights on the nature of a certain class of localized states, the quantum equivalent of the classical periodic orbits. There is a dramatic change in the character of the localized states as a function of α. They exhibit widely varying localization length depending on whether α is in the stable/unstable or in the transition domain of the underlying classical periodic orbit. The log negativity and negativity measures of separability was used in quantum information theory, to understand the underlying structure of the localized states and the regular states. This measure compliments the information entropy measure and show saturation of entanglement at a certain value of α. In addition, It is found that the distribution of avoided crossing show intricate structure and influences the nature of the localized states.

(**Dilip Angom, Jayendra Bandopadhyay, V. B. Sheorey, A. Lakshminarayan** and M.S.Santhanam)

The research activities of this division over the past year are summarized as follows.

Coherence Properties of Sunlight

The coherence properties of sunlight were first studied by Verdet around 1869 and were later examined by other scientists. However, all the previous calculations assumed that the Earth is in the far zone of the Sun, an assumption that is incorrect. A surprising property of radiation from incoherent sources emerges from an investigation of why Verdet's result is correct.

(**G.S. Agarwal**, G. Gbur and E. Wolf)

Scheme to Measure Quantum Stokes Parameters and their Fluctuations and Correlations

Polarization of light is a well studied subject. Text book descriptions of light polarization are based on the Stokes parameters. Methods for measuring the Stokes parameters are also well known. The Stokes parameters have been generalized in several ways. Recently, there has been considerable interest in the so called quantum Stokes parameters to describe the polarization characteristics of a non-classical field possessing very strong quantum fluctuations. A scheme to measure quantum Stokes parameters, their fluctuations and correlations has been proposed. The proposal involves measurements of intensities and intensity-intensity correlations for suitably defined modes, which can be produced by a combination of half wave and quarter wave plates.

(**G.S. Agarwal** and S. Chaturvedi)

Storage and Retrieval of Light Pulses at Moderate Powers

It is demonstrated that it is indeed possible to store and retrieve probe pulses, which are not necessarily weak, in an atomic media in the Λ -configuration. We find that the retrieved pulse remains a replica of the original pulse, although there is overall broadening and loss of intensity. The loss of intensity can be understood in terms of the dependence of absorption on the intensity of the probe. Our calculations include the dynamics of the control field, which becomes especially important as the intensity of the probe pulse increases. The theory of adiabatons to understand our numerical results on the storage and retrieval of light pulses at moderate powers are used.

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

Slowing Down and Stoppage of Light in Doppler Broadened Systems

It is shown that the propagation of light in a Doppler broadened medium can be slowed down considerably even though such medium exhibits very flat dispersion. The slowing down is achieved by the application of a saturating counter propagating beam that produces a hole in the inhomogeneous line shape. In atomic vapors, we calculate group indices of the order of 10^3. The calculations include all coherence effects. Further it is shown, how the application of a coupling field connecting the two lower metastable states of a Lambda system facilitates stoppage of light in a coherently driven Doppler broadened atomic medium via electromagnetic induced transparency.

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

Atomic Absorbers for Controlling Pulse Propagation in Resonators

Pulse propagation through a Fabry Perot cavity with silver mirrors that contain macroscopic samples of resonant absorbers has been considered. It is shown that the pulse velocity can be tuned from subluminal to superluminal in a strongly coupled atom cavity system. The effects of the interplay of cavity and absorbers are delineated. We demonstrate the saturation effects of pulse advancement with increasing mirror thickness and atomic damping.

(**G.S. Agarwal**, V.S.C. Manga Rao and S. Dutta Gupta)

Group Index for Pulse Propagation & Sub and Superluminal Propagation in a Left Handed Medium

All naturally occurring materials are known to exhibit positive values for the material constants $\varepsilon(\omega)$ and

$\mu(\omega)$, which determine the refractive index of a material. However, recently, there have been reports of new, artificial materials which can have negative values for the material parameters, exhibiting negative index for refraction of light. The propagation of a narrow-band pulse with center frequency at the region of negative index through this medium have been studied. It is found that the group delays of pulse propagation can be very large for a negative medium in comparison to the usual case of positive refraction. Superluminal passage and saturation of phase time in the same material, albeit in a different spectral region have also been demonstrated.

(**R. Arun, G.S. Agarwal** and S. Dutta Gupta)

Measurement of the Local Field Effects of the Host on the Life Time of Embedded Emitters

Experimental results on the variation of the radiative lifetime of Eu^{3+} ion embedded in a dielectric with the refractive index n are reported. 1 mol % of Eu^{3+} into the binary glass system $xPbO–(1–x)B_2O_3$ is doped. By varying x a fairly large variation of the refractive index from 1.7 to 2.2 is achieved enabling to study the local field effects for the first time for ions doped in a solid glassy material. Measurements are in agreement with the so-called real cavity model. The present measurements are free from the complications arising from reorganizational effects in solvents.

(**G.S. Agarwal**, G. Manoj Kumar and D. Narayana Rao)

Influence of Damping on the Vanishing of the Linear Electro-optic Effect in Chiral Isotropic Media

Using first principles, it is demonstrated that radiative damping alone cannot lead to a nonvanishing linear electro-optic effect in a chiral isotropic medium. This conclusion is in contrast with that obtained by a calculation in which damping effects are included using the standard phenomenological model. It is shown that these predictions differ because the phenomenological damping equations are valid only in regions where the frequencies of the applied electromagnetic fields are nearly resonant with the atomic transitions. Also it is shown that collisional damping can lead to a nonvanishing linear electro-optic effect, but with a strength sufficiently weak, it is unlikely to be observable under realistic laboratory conditions.

(G.S. Agarwal and R.W. Boyd)

Single-atom and Two-atom Ramsey Interferometry with Quantized Fields

Implications of field quantization on Ramsey interferometry are discussed and general conditions for the occurrence of interference are obtained. Interferences do not occur if the fields in two Ramsey zones have a precise number of photons. However, in this case it is shown how an analog of Hanbury-Brown Twiss photon-photon correlation interferometry can be used to discern a variety of interference effects as the two independent Ramsey zones get entangled by the passage of the first atom. Interferences are restored by working with fields at a single-photon level. Generation of entangled states including states such as $|2,0\rangle+e^{i\theta}|0,2\rangle$ is discussed.

(**G.S. Agarwal**, **P.K. Pathak** and M.O. Scully)

Laser-induced Breakdown of the Magnetic-field-reversal Symmetry in the Propagation of Unpolarized Light

It is shown that a medium, under the influence of a coherence control field that is resonant or close to resonance to an appropriate atomic transition, can lead to very strong asymmetries in the propagation of unpolarized light when the direction of the magnetic field is reversed. We show how electromagnetically induced transparency (EIT) can be used in atomic vapor to mimic this magnetochiral effect that occurs in natural systems.

(G.S. Agarwal and S. Dasgupta)

Strong Subadditivity Inequality for Quantum Entropies and Four-particle Entanglement

The strong subadditivity inequality for a three-particle composite system is an important inequality in quantum information theory which can be studied via a four-particle entangled state. Two three-level atoms in λ con-

figuration interacting with a two-mode cavity and the Raman adiabatic passage technique are used for the production of the four-particle entangled state. Using this four-particle entanglement, we study various aspects of the strong subadditivity inequality.

(A. Biswas and G. S. Agarwal)

Quantum Teleportation, Quantum Networks and Memory using Cavity QED

A protocol for the transfer of an unknown atomic state from one cavity to a distant cavity is presented. This protocol is based on sequential interaction of a detuned two-mode optical cavity with three-level atoms in Lambda configuration in their ground states. A scheme for quantum networking between the distant cavities based on an atomic channel is proposed. This is unlike the other networking protocols, which use a photon as a carrier between the cavities and thus are prone to decoherence due to photon absorption. The possibility of an efficient quantum memory for the entangled states of the field in the cavity is discussed. The entanglement can be stored in the ground states of the atom and can be retrieved as well in another cavity.

(A. Biswas and G. S. Agarwal)

Coherent States for Exactly Solvable Potentials

A general algebraic procedure for constructing coherent states of a wide class of exactly solvable potentials, e.g., Morse and Pöschl-Teller, is given. The method, a priori, is potential independent and connects with earlier developed ones, including the oscillator-based approaches for coherent states and their generalizations. This approach can be straightforwardly extended to construct more general coherent states for the quantum-mechanical potential problems, such as the nonlinear coherent states for the oscillators. The time evolution properties of some of these coherent states show revival and fractional revival, as manifested in the autocorrelation functions, as well as, in the quantum carpet structures.

(T. Shreecharan, P.K. Panigrahi, and J. Banerji)

Unified Algebraic Approach to Few- and Many-body Correlated Systems

The present work substantially extends the results of our earlier work, where the equivalence of the Calogero-Sutherland model to decoupled oscillators has been established. A number of few- and many-body interacting models are studied and the relationship between their respective Hilbert spaces, with that of oscillators, is found. The inadequacies of the present technique are pointed out and a method for solving linear differential equations is used to diagonalize the Sutherland model and establish a precise connection between this correlated system's wave functions, with those of the free particles on a circle. It is shown how a novel method of solving linear differential equations emerges naturally in this process. Applications of the same to Hypergeometric equation and its generalizations are illustrated.

(**P.K. Panigrahi** and N. Gurappa)

Development of an Approximation Scheme for Quasi-exactly Solvable Systems

Quasi-exactly solvable quantal systems have manifested in physical systems ranging from anharmonic oscillators to double-well potentials appearing in the description of ring lasers. A recently developed method is employed to not only find the analytically obtainable part of the eigenspectra, but also to develop a perturbation theory to determine the low-lying states to the desired accuracy.

(Rajneesh Atre and P.K. Panigrahi)

Differentiating Normal and Cancer Tissues through the Wavelet Transform of Fluorescence Data

Fluorescence spectroscopy is being increasingly used for characterization of biological tissues because of its sensitivity. However, extraction of statistically significant parameters to differentiate various tissue types, e.g., cancerous, benign and normal has been a challenge. In this context, we have employed Wavelet Trans-

form for the first time to extract subtle information from the fluorescence data for a clear tissue differentiation.

(**P.K. Panigrahi**, N. Agarwal, S. Gupta, Bhawna, A. Pradhan & K. Vishwanathan)

Translational Entanglement of Dipole-Dipole Interacting Atoms in Optical Lattices

It is proposed to investigate a realization of the position- and momentum-correlated Einstein-Podolsky-Rosen (EPR) states that have hitherto eluded detection. The realization involves atom pairs that are confined to adjacent sites of two mutually shifted optical lattices and are entangled via laser-induced dipole-dipole interactions. The EPR "paradox" with translational variables is then modified by lattice-diffraction effects, and can be verified to a high degree of accuracy in this scheme.

(**B. Deb**, T. Opatrny and G. Kurizki)

Model Study on the Photoassociation of a Pair of Trapped Atoms into an Ultralong-range Molecule

Using the method of quantum-defect theory, we calculate the ultra-long-range molecular vibrational states near the dissociation threshold of a diatomic molecular potential which asymptotically varies as $-1/R^3$. The Franck-Condon overlap integrals between the harmonically trapped atom-pair states and the ultra-long-range molecular vibrational states are estimated and compared with their values for a pair of untrapped free atoms in the low-energy scattering state. We find that the binding between a pair of ground-state atoms by a harmonic trap has significant effect on the Franck-Condon integrals. Trap-induced binding between two ground-state atoms may facilitate coherent photoassociation dynamics between the two atoms and the photoassociated diatomic molecule.

(**B. Deb** and L. You)

Topological Charge Inversion of a Vortex

The field associated with the vortices possesses a helical wave front and the direction of rotational flow around the phase singularity defines the sign of topological charge associated with the vortex. In optical field, vortices find variety of applications in optical tweezers, optical spanners, optical trapping of atoms and also in quantum information and computation. A canonical vortex using a computer generated hologram, which was converted to a non-canonical vortex using a cylindrical lens is produced. The same ABCD law for vortex propagation that was used to find out the trajectory of the canonical and non-canonical vortex has been used to show that for a non-canonical vortex topological charge gets inverted as it propagates. The point of inversion was found to be same experimentally as well as theoretically, validating our theoretical treatment of the process of charge inversion.

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

Quantum Disentanglement Eraser: A cavity QED Implementation

A possible experimental scheme of the Garisto-Hardy disentanglement eraser based on cavity QED system is presented. This scheme can be used for a delayed choice quantum eraser. It also allows us to acquire single qubit control over teleportation of an arbitrary binary state.

(**G.S. Agarwal**, M.S. Zubairy and M.O. Scully)

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

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

(A. Biswas and G.S. Agarwal)

Preparation of W, GHZ, and two-qutrit states using bimodal cavities

It is shown how one can prepare three-qubit entangled states like W states, Greenberger-Horne-Zeilinger states as well as two-qutrit entangled states using the multiatom two-mode entanglement. A technique of preparing such a multi-particle entanglement using stimulated Raman adiabatic passage is proposed. A collection of three-level atoms in Λ - configuration simultaneously interacting with a resonant two-mode cavity is considered for this purpose. Our approach permits a variety of multiparticle extensions.

(A. Biswas and G.S. Agarwal)

Implementing Deutsch-Jozsa Algorithm using Light-shifts and Atomic Ensembles

A new optical scheme to implement Deutsch-Jozsa algorithm using ac Stark shifts is presented. The scheme uses an atomic cell consisting of four-level atoms interacting dispersively with a field. This leads to a Hamiltonian in atom-field basis which is quite suitable for quantum computation. It is shown how one can implement the algorithm by performing proper one-qubit and two-qubit operations. It is emphasized that in our model, the decoherence is expected to be minimal due to our usage of atomic ground states and freely propagating photon.

(S. Dasgupta, A. Biswas, and G. S. Agarwal)

Superluminal Propagation via Coherent Manipulation of Raman Gain Process

A novel method of manipulating the Raman process by using a coherent control field which leads to splitting of the Raman gain peak into a doublet and anomalous dispersion in the region between the gain peaks is presented. It is shown how the region of almost no Raman gain and strong anomalous dispersion is ideally suited for producing superluminal propagation. In particular, it is shown that the group index for ^{23}Na condensate could be in the range -10^3 to -10^4.

(G. S. Agarwal and S. Dasgupta)

Sub- and Superluminal Propagation of Intense Pulses in Media with Saturated and Reverse Absorption

Models for the propagation of intense pulses in solid state media which can have either saturated absorption or reverse absorption have been developed. Subluminal propagation in ruby and superluminal propagation in alexandrite as three and four level systems, respectively, coupled to Maxwell's equations is modelled. Results well beyond the traditional pump-probe approach are presented and explained the experiments of Bigelow et al. on solid state materials.

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

Mesoscopic Superposition of States with Sub-Planck Structures in Phase Space

A cavity quantum electrodynamics method is proposed, using dispersive interaction between atoms and a high quality cavity to realize the mesoscopic superposition of coherent states which would exhibit sub-Planck structures in phase space, i.e., the structures at a scale smaller than the Plank's constant. These structures are direct signatures of quantum coherence and are formed as a result of interference between the two superposed cat states. In particular focus is on a superposition involving four coherent states. Interferences in the conditional measurements involving two atoms are shown (**Fig. 5.1**).

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

Interferometric measurement of the degree of polarization and control of the contrast of intensity fluctuations

A technique for determining the polarimetric characteristics of light by measuring the contrast of the intensity fluctuations in an interferometric setup has been introduced. The method permits simultaneous measurement of the degree of polarization and of the second normalized Stokes component, which is related to the ellipsometric parameters' azimuth and ellipticity, based on only two measurements. It is shown that by using

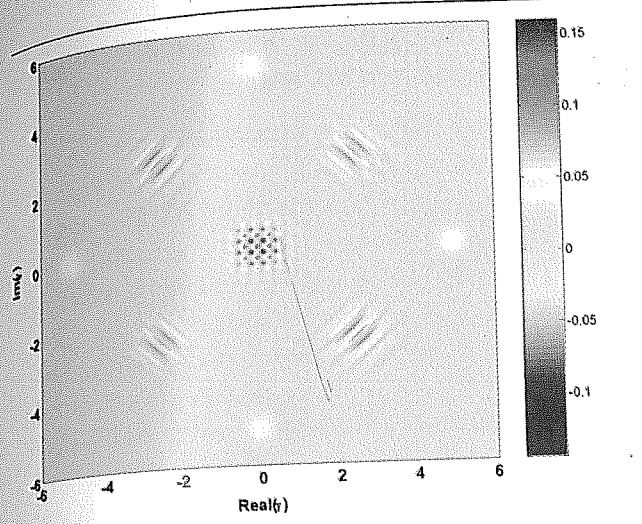


Fig. 5.1: The Wigner function for the mesoscopic superposition of four coherent states $N[|\alpha>+|i\alpha>+|-\alpha>+|-i\alpha>]$, *for* $|\alpha|=5$

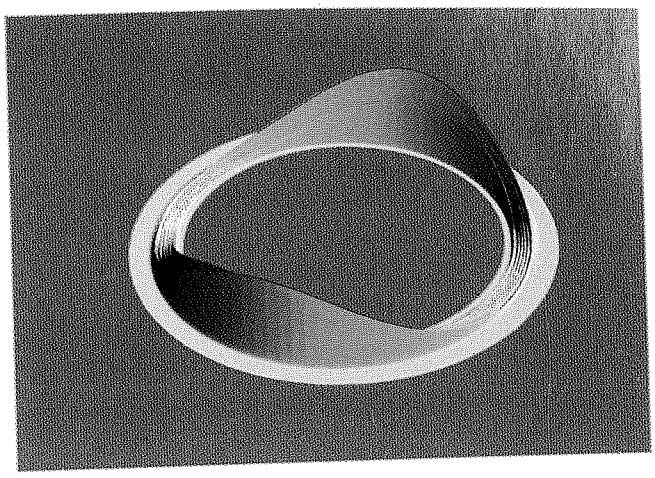


Fig. 5.2 : A two way split of the initial molecular wave packet

phase modulation the signal-to-noise ratio can be increased to as much as 40% under certain conditions.

(G.S. Agarwal, M. Mujat and A. Dogariu)

Quantum-information Entropies of the Eigenstates and the Coherent State of the Pöschl-Teller Potential

The position and momentum space information entropies, of the ground state of the Pöschl-Teller potential, are exactly evaluated and are found to satisfy the bound obtained by Beckner, Bialynicki-Birula, and Mycielski. These entropies for the first excited state, for different strengths of the potential well, are then numerically obtained. Interesting features of the entropy densities, owing their origin to the excited nature of the wave functions, are graphically demonstrated. The position space entropies of the coherent state of the Pöschl-Teller potential, which is known to show revival and fractional revival are computed. Time evolution of the coherent state reveals many interesting patterns in the space-time flow of information entropy.

(R. Atre, A. Kumar, C. Nagaraja Kumar and P.K. Panigrahi)

Nonlinear Compression of Exact Solitary Waves in Asymmetric Twin-core Fibers

A novel pulse compression technique based on exact solutions to the nonlinear Schrödinger equation (NLSE) interacting with a source, with distributed dispersion, nonlinearity and gain or loss is demonstrated. It is shown that this model is appropriate for the pulse propagation in asymmetric twin-core fibers. The chirped pulses are compressed due to the nonlinearity as well as dispersion management as also due to the space dependence of the gain coefficient. We also obtain singular solitary wave solutions, pertaining to extreme increase of the amplitude due to self focusing.

(P.K. Panigrahi and T.S. Raju)

Fractional Revival of a Diatomic Molecular Wave Packet

The time evolution of a diatomic molecular wave packet for which both the vibrational and rotational motions have been taken into account have been studied. It is predicted and numerically confirmed that at certain instants of time, a suitably prepared initial wave packet will fractionally revive, that is, split up into an integer number of replicas **(Fig. 5.2)**.

(J. Banerji and Suranjana Ghosh)

Lower Atmosphere

Seasonal Variations in Trace Gases over the Bay of Bengal

Measurements of O_3 and anthropogenically emitted trace gases like CO, CH_4 and light non-methane hydrocarbons (NMHCs) have been studied in different seasons over this region. The continental emitted pollutants are transported from the Asian countries over the Bay of Bengal during the northeast (NE) wind flow while the clean marine air flows during the southwest (SW) monsoon. Two cruises were conducted when the general wind pattern was NE during 19 February to 28 March 2001 (BOB-2001) and 19 to 28 February 2003 (BOB-2003). Another cruise was conducted from 14 September to 12 October 2002 (BOB-2002), when the wind flow was from SW direction just reverse of what was during the other two cruises. Mean mixing ratios of O_3, CO, and CH_4 observed during these campaigns are shown in **Fig. 6.1**. Both O_3 and CO were found to be lowest during BOB-2002. Methane is well mixed within the troposphere and does not show significant seasonal differences. Relatively long-lived NMHCs species (like ethane and acetylene) show seasonal variation, while no significant seasonal differences are observed in reactive (short-lived) NMHCs over this region.

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

Transport Effects on the Distributions of NMHCs at Ahmedabad and Mt. Abu

Measurements of anthropogenic light non-methane hydrocarbons (NMHCs) are made at Ahmedabad and Mt. Abu. These sites are about 200 km apart from each other and therefore general wind patterns do not show significant differences. Ahmedabad is representative of fully urbanized region with large number of industries. On the other hand being an elevated site with minimum local emissions, Mt. Abu represents a clean background environment. Local emissions of NMHCs dominate their distributions at Ahmedabad, while at Mt. Abu transport from the source regions plays an important role in their mean levels. It is observed that annual mean values of C_2-C_4 NMHCs at Ahmedabad are higher by factors of 3-9 with respect to the mean values at Mt.Abu. Due to efficient transport (lifetimes are higher than the transport time) of ethane and acetylene the concentrations are relatively higher for these two compounds even at Mt. Abu. Among all the NMHCs measured, propane dominates (23%) at Ahmedabad while ethane (39%) dominates at Mt. Abu (**Fig. 6.2**).

(L.K. Sahu, S. Venkataramani and S. Lal)

Vertical Distributions of Ozone, Humidity and Temperature

Concentrations of ozone at surface and in the troposphere are increasing due to increasing levels of pol-

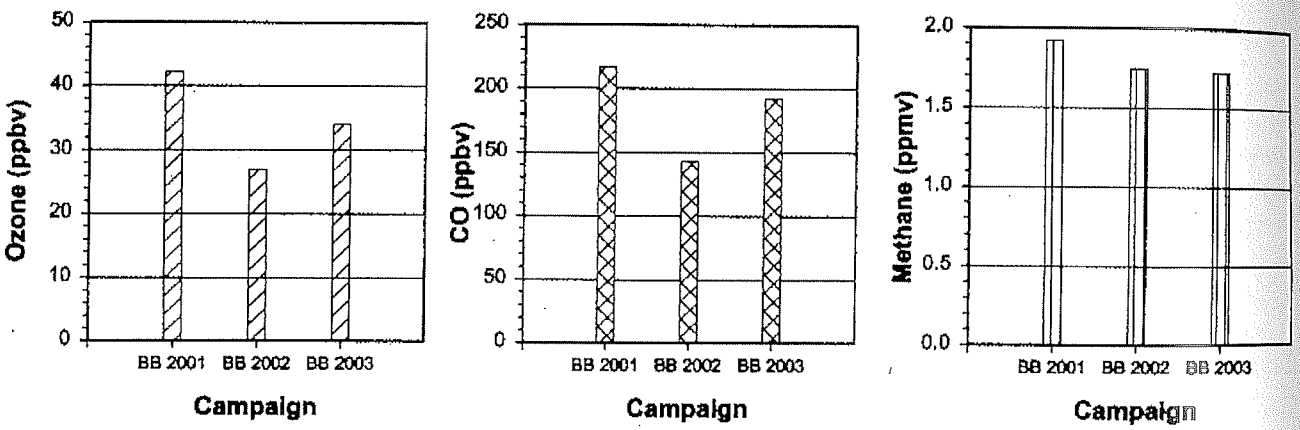


Fig. 6.1 A comparison of mean values of O_3, CO and CH_4 during three different cruise campaigns (2001-2003) over the Bay of Bengal

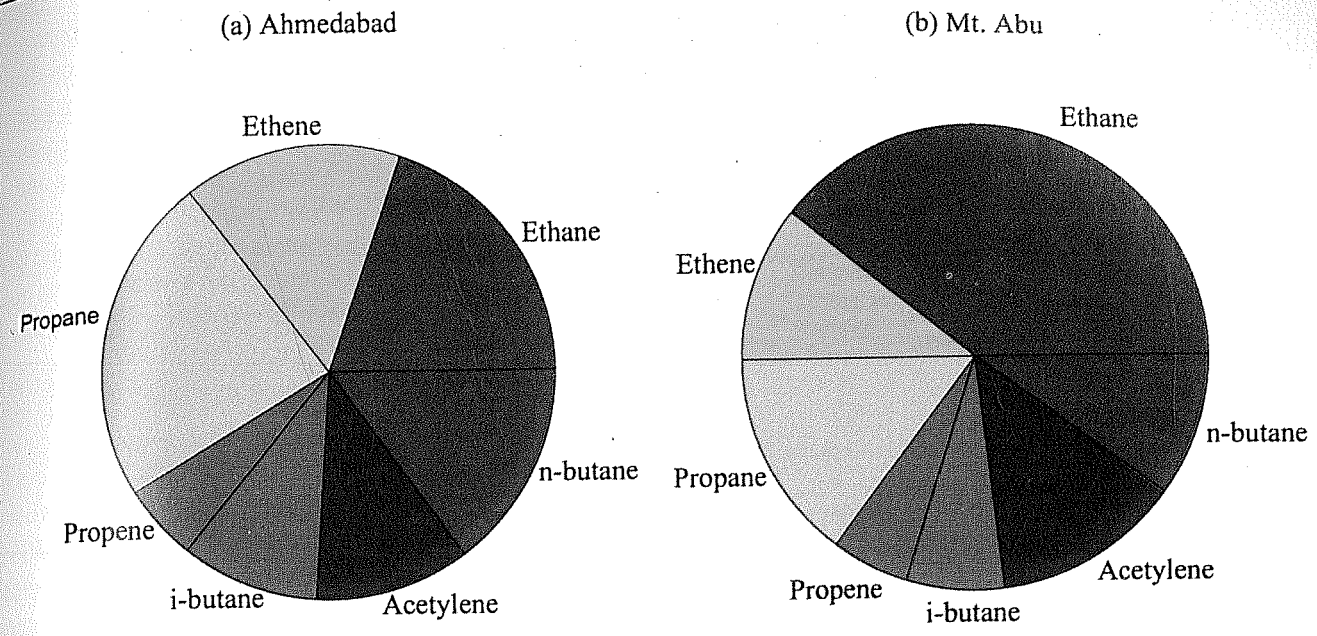


Fig. 6.2 Abundance (percentage) of various C_2-C_4 NMHCs measured during 2002 at Ahmedabad and Mt.Abu

lutants at many sites over the globe, which could cause environmental and climatic changes. In order to understand changes in ozone in the troposphere, which are caused by natural as well as man-made activities, we have initiated a programme at PRL under ISRO-GBP to measure vertical distributions of ozone, humidity and temperature simultaneously using balloon-borne sensors. Under this new programme, rubber balloons carrying ozone and radiosondes are being launched fortnightly from PRL campus at Ahmedabad. The first balloon flight of this series was made on 16 April, 2003. So far 19 balloon flights have been made most of them reaching upto the ceiling height of about 33 km. Most of these flights also carried a global positioning system (GPS) which gives balloon coordinates, wind direction and wind speed. Large variability in ozone distribution is observed at lower heights particularly within the planetary boundary layer (PBL) as well as in the stratosphere. Occasionally, sharp increases in ozone are observed near the tropopause region. The total ozone amount generally matches with the Dobson measurement, which is also being operated regularly at PRL.

(S. Lal, S. Venkataramani, T.A. Rajesh, Shilpi Gupta, S. Desai, T.K. Sunilkumar and K.S. Modh)

Micro Pulse Lidar (MPL) Study of Vertical Profiles of Aerosols over Ahmedabad

The micro pulse lidar (MPL; originally a NASA-GSFC design) uses an Nd:YLF laser which emits 1047 nm wavelength and the inbuilt second harmonic generator converts it to 523.5 nm. Each laser pulse is of 10 ns duration with energy around 3μJ and the pulse repetition frequency is presently configured at 2500 Hz. The lidar detects the backscattered radiation from air molecules and aerosols up to about 10 km during daytime and up to about 30 km during night. The Micro Pulse Lidar is in operation at PRL since February 2002. Seasonal and annual variations in the vertical profiles of aerosols over Ahmedabad are being studied. **Fig. 6.3** shows the average monthly aerosol extinction profiles for a few selected months measured over Ahmedabad. During summer months there is an increase in the aerosol back scattering in the 2 to 5 km altitude region compared to that during winter months. The increase is believed to be due to the hygroscopic growth of the sulfate like particles found over urban locations supported by the increase in relative humidity at higher altitudes during summer monsoon. Nevertheless during dust storm activi-

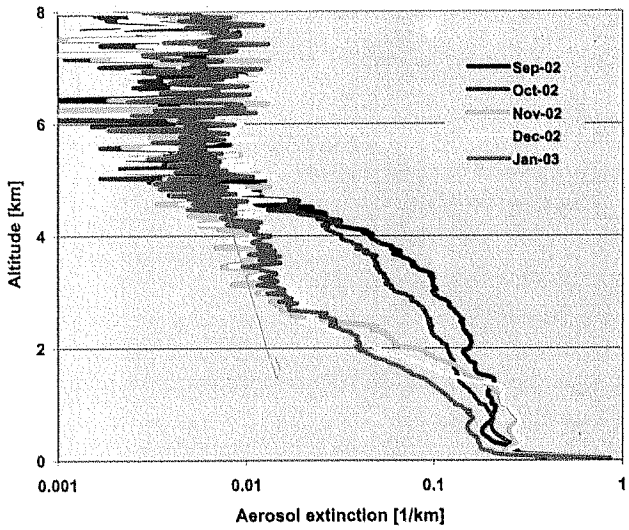


Fig. 6.3 Micro pulse lidar measured monthly mean aerosol profiles over Ahmedabad for a few selected months. Note the decreased aerosol amount in the 2 to 4 km region during the winter months than compared to September, October months as the boundary layer collapses to lower heights in winter.

ties, which are more prevalent during the premonsoon period, the increase in aerosol amount is seen in only the lower altitudes, surface to about 3 km, indicating that the locally produced dust aerosols dominate over Ahmedabad in comparison to that brought from distant places. Lidar study helps to identify the altitude distribution of the particles that are important in the estimation of the altitude variation in aerosol radiative forcing.

(H. Gadhavi and A. Jayaraman)

Inter and Intra-annual Variation of Aerosol Characteristics over Ahmedabad

Megacities are sources of a variety of anthropogenic aerosols that lead to serious environmental problems including climate change. It is therefore necessary to quantify the export fluxes of these pollutants from megacities into the background atmosphere. According to UNEP (2001) report, concentration of suspended particulate matter (SPM) in some of the Indian cities far exceed the standards set by WHO. Continuous and simultaneous measurements of aerosol optical depth (AOD), column integrated ozone and water vapour concentrations, surface level aerosol mass concentration and size distribution are being taken over Ahmedabad from early 2002. Seasonal variation of different aerosol parameters shows that there is a systematic increase in AOD at all wavelengths during summer months and an increase in the number of smaller size particles with respect to larger particles from summer to winter and vice-versa. Additional studies have been initiated for the measurement of absorption and scattering coefficients of aerosols. There is a diurnal pattern in the variation of black carbon mass concentration as well as in the scattering coefficient of aerosols. Derivation of the chemical composition of aerosols is attempted by model fitting the measured aerosol optical depth spectrum using the Optical Properties of Aerosol and Cloud (OPAC) model. The experimentally derived aerosol single scattering albedo will be used to constrain the model fitting.

(D. Ganguly and A. Jayaraman)

Study on Satellite Retrieval of Aerosol Optical Depth over Land

The natural and spatial spread of aerosols over India is very complex, with a mixture of soot, sulfates, mineral dust etc., due to which constructing a general aerosol model for the subcontinent is not easy. Satellite observations, however with limited accuracy, can provide the necessary data for understanding the spatial and temporal behaviour of aerosols over the region. Radiation measured by a satellite contains reflection from the earth's surface as well as the scattered radiation from the atmosphere. Satellite study of aerosols over oceans is comparatively more accurate on account of the dark background they provide to the scattered radiation whereas that over land is more challenging because of the distinction that has to be made between the radiation reflected by the surface and that by the atmosphere. As a case study, MODIS (MODerate resolution Imaging Spectroradiometer, onboard the Terra/Aqua satellites) derived aerosol optical depth over Ahmedabad for two complete annual cycles has been compared with the ground based AOD observations. While the satellite data reproduced the overall seasonal pattern observed by the sun-photometer there are large

differences in the absolute values. Possible causes include erroneous account of land reflectance, ambient relative humidity etc. A new start has been made to account for these in models used in the inversion algorithm. A software package is also being developed to simulate the scattered radiation field at the top and bottom of the atmosphere for different aerosol types.

(A. Misra and A. Jayaraman)

Aerosol Radiative Forcings over the Oceanic Regions Surrounding the Indian Subcontinent during Winter Monsoon Season

The yearly- and monthly-mean variations in the clear-sky shortwave aerosol direct radiative forcings are estimated over Coastal India (CI), the Arabian Sea (AS) and tropical Indian Ocean (TIO) during winter monsoon season. Adopting a hybrid approach of using the measured aerosol optical depths (AOD) during 1996-2000, fitting them with OPAC and employing a discrete ordinate radiative transfer code the radiative forcings are calculated. Aerosol radiative forcings over Bay of Bengal (BOB) from the AODs obtained during February 2001 are estimated and compared. The yearly- and monthly-mean variations in aerosol forcings are found to exhibit good agreement with AOD variations over these oceanic regions. Top of the Atmosphere (TOA) forcings are found to be -9 (BOB), -7 (CI), -6 (AS) and about -2 Wm^2 over TIO during February. Surface (SFC) forcing is higher over BOB with a value of -31 Wm^{-2}, while the SFC forcings over CI, AS and TIO are estimated to be -19, -13 and -2 Wm^2 (**Fig. 6.4**). Atmosphere (ATM) forcing is about 21 Wm^2 over BOB, while it is 13 Wm^{-2} over CI, 6 Wm^{-2} over AS and < 0.5 over TIO. This comparison shows that the forcings are the highest over BOB when compared to the other oceanic regimes. The high atmospheric absorption over Bay of Bengal is attributed to the presence of higher soot content. The large atmospheric absorption estimated over BOB, CI and AS is found to be a feature of the other polluted ocean and land regions, such as the Atlantic Ocean, Mediterranean, equatorial Africa and Amazon.

(S. Ramachandran)

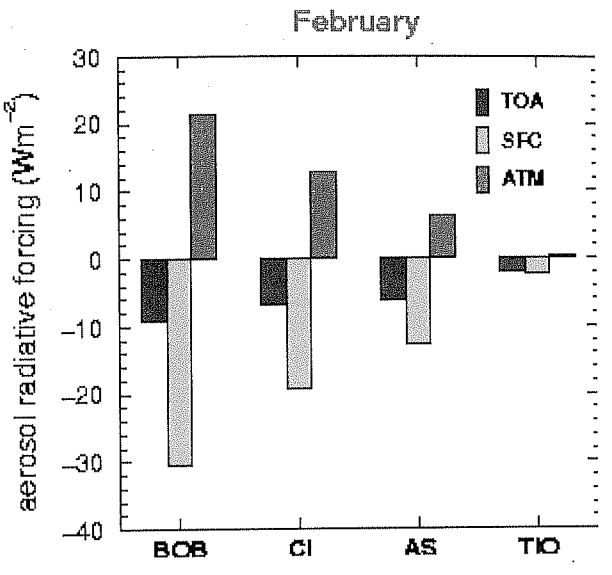


Fig. 6.4 The mean aerosol radiative forcings estimated over Bay of Bengal in February 2001 are compared with those estimated over Coastal India (CI), the Arabian Sea (AS) and tropical Indian Ocean (TIO). CI, AS and TIO radiative forcings are calculated for the February monthly-mean AOD spectra and are the average of the four INDOEX cruises conducted during 1996-1999.

Yearly- and Monthly-mean Variations in Spectral Aerosol Optical Depths over the Arabian Sea and Indian Ocean

Spectral aerosol optical depths measured in situ in the 0.4-0.85μm during 1996-2000 over the Arabian Sea and tropical Indian Ocean are analyzed and the yearly- and monthly-mean variations in the aerosol optical depths are studied. The 0.4 μm AODs are found to be higher by a factor of three with respect to the 0.85μm AODs indicating the dominance of smaller size aerosols over these oceanic regimes. The AODs are found to exhibit interannual and monthly variations. On the yearly-mean scale the AODs are found to exhibit an increasing trend over CI and AS, while the AODs are found to decrease over TIO during the 5-year period. Trend lines indicate that over Coastal India the AODs are found to increase by about 10% during the 5-year period while over AS the AODs have increased by about 5-8% in the 0.4-0.85μm

wavelength region. Over the Indian Ocean the AODs have decreased by about 20% per year.

(S. Ramachandran)

A GCM Study of Variabilities in Stratospheric Responses due to Pinatubo Aerosols

The radiative and dynamical responses in the stratosphere due to Pinatubo aerosols are determined by doing an ensemble of eight GCM integrations with different initial conditions and with observed aerosol properties as input. Equator-to-pole temperature gradients in 1991/92 winter in the northern hemisphere are different in each ensemble run. The ensemble results show that the stratosphere can evolve quite differently depending on the initial meteorological conditions with differing equator-to-pole temperature gradients and significant year-to-year variability in the polar temperatures. A strong negative correlation exists in the lower stratosphere between the temperature anomalies obtained in the tropics and the polar latitudes.

(**S. Ramachandran** and V. Ramaswamy)

Upper Atmosphere

Geomagnetic Storms and Ionospheric Effects at Anomaly Crest Region

Geomagnetic storms of different strengths and their response to F_2 - region of ionosphere near the anomaly crest region are studied based on the interplanetary, geomagnetic and ionospheric data during the solar maximum period of 1999-2001. The southward IMF is an essential precondition for the formation of geomagnetic storms. Response to ionosphere is examined from the ionospheric F_2 region data.

The storm-time response to F_2-region of ionosphere is studied using ionosonde (1989-91, 1999-2001) and VHF scintillation (1999-2001) data recorded at Ahmedabad. The ionosonde data show both positive and negative effects for foF_2. The negative storm effects are much more pronounced than the positive storm effects. The negative storm effects that occur in the post-midnight are mostly accompanied by the increase in h'F. The decrease in foF_2 due to storm induced circulation that brings the gas with depleted O/N_2 ratio, dominates the increase in foF_2 due to the increase in h'F, and results in the net decrease in foF_2. The penetrating magnetospheric and high-latitude electric fields and the electric fields generated by the disturbance dynamo play important role. The probability of occurrence of scintillations in the post-midnight is enhanceed under the storms in which Dst goes below -75 nT in the post-midnight to dawn sector. Reversal of the equatorial ionospheric electric field due to the penetration of storm-time magnetospheric and high-latitude electric fields explains such scintillation occurrence.

(**H. Chandra, Som Sharma** and Sushil Kumar)

Study of Gravity Waves using Airglow Imaging

The Airglow imaging system has been upgraded and deployed for the study of gravity waves.The campaigns were conducted from Gurushikhar during November 2003 and from Kavalur during January 2004 to March 2004. Preliminary analysis of data has shown very encouraging results. Signatures of gravity waves could be seen in 630 nm oxygen emission, at several occasions in the night. Detailed analysis of the data is underway.

(H S S Sinha, R N Misra, N Dutta, P K Rajesh, M B Dadhania and S B Banerjee)

Optical Signatures of Some Special ESF Structures

A co-ordinated experiment with Indian MST radar and a narrow band optical photometer was carried out from Gadanki during February-April, 2004. The optical signatures corresponding to special ESF events at two thermospheric emission lines (630.0nm and 777.4nm) were found to be different from event to event. The 777.4 nm intensity variation over zenith showed anti-correlation with the 630.0 nm intensity variation over zenith when the large scale ESF structure encompassed the

peak altitude of both the emission lines (**Fig. 6.5**). However, during that interval, the 777.4 nm intensity in the zonal direction (east) varied identically with the 630.0 nm intensity variation over zenith and 630.0 nm intensity in the zonal direction varied identically with the 777.4 nm intensity variation over zenith. In addition to that, it is found that the vertical columnar intensity of OI 630.0 nm airglow exceeded the slanted columnar intensity in the presence of large bottomside structure. Depending upon the altitude of the plume structures and the bottomside structures, the optical signatures in 630.0 nm and 777.4 nm are found to be in conformity with the micro and macro structures of ESF. These cases have been critically investigated to understand the role of electric field in the thermospheric airglow emissions. This work is carried out in collaboration with National MST Radar Facility, Gadanki.

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

Micro Variations in the Thermospheric Nightglow Emission Intensities during a Space Weather Event

Earlier investigation revealed the presence of micro variations in the thermospheric airglow intensities which are associated with the "plume" structures obtained by the VHF radar during spread-F events. These micro variations were found to be absent during non-ESF nights. These observations pertain to geomagnetically "quiet" conditions. However, during the period of co-ordinated experiment with Indian MST Radar in February, 2004, the thermospheric nightglow emission intensities showed micro variations during geomagnetically "disturbed" condition and on nights when spread-F events were absent. These micro variations are believed to be due to the penetration of storm-time magnetospheric electric field in the low latitude. The role of perturbation electric field in the thermospheric airglow emission is investigated. This work is carried out in collaboration with National MST Radar facility.

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

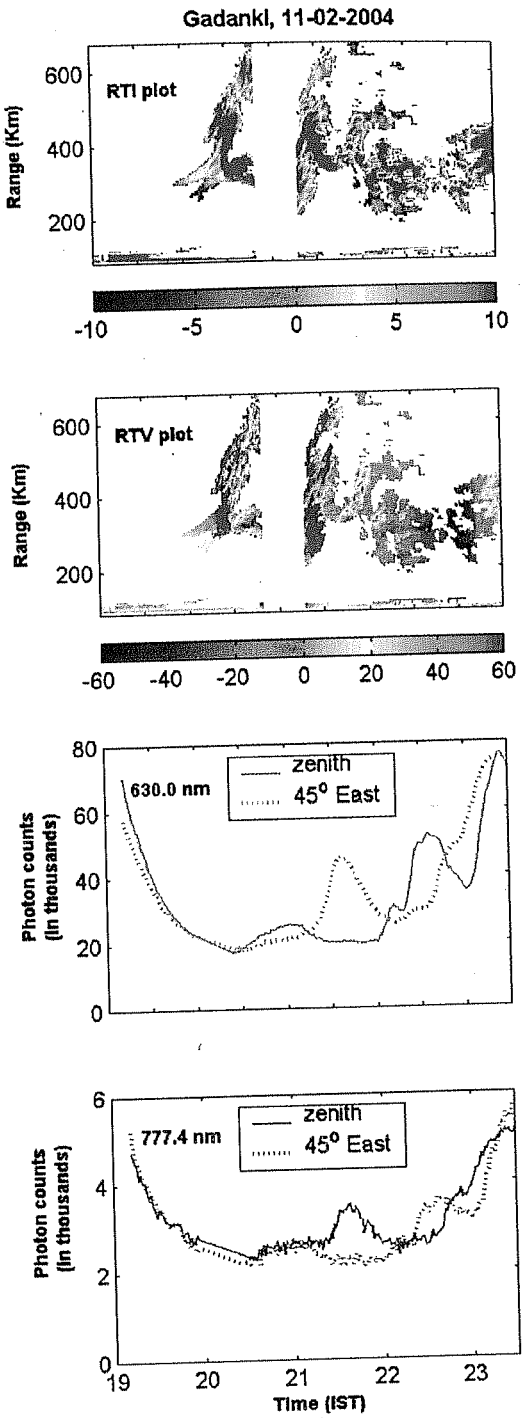


Fig.6.5 Co-ordinated observations by VHF Radar and the narrow band photometer revealing the airglow responses corresponding to one of the special structures of ESF

OI 630.0 nm Dayglow Intensity Variations during a Disturbed Geomagnetic Condition in February, 2002 – a Case Study

It is known that geomagnetic storms trigger the generation of large scale traveling ionospheric disturbances (TID) which can propagate upto the low and equatorial latitudes. However, these TIDs and their parameterization are yet to be comprehensively understood. By scanning in the meridional direction during a geomagnetic storm event in February, 2002, OI 630.0 nm dayglow intensities were obtained. By carrying out a suitable harmonic analysis of the dayglow intensity fluctuations, an attempt is made to identify the TIDs associated with this particular storm.

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

Laboratory Astrophysics

Recoil Ion Momentum Spectrometry

A recoil ion momentum spectrometer has been built for studying ionization of atomic oxygen, and fragmentation of molecules by a laser (multi-photon ionization) or by electron impact ionization. The spectrometer is operational and electron-impact experiments have started. The spectrometer is essentially an imaging device, but it also records the time of arrival of ions. **Fig. 6.6** shows an image of the ion track created by the passage of electron beam. The position and time information can be converted into a three-dimensional velocity or momentum map. During the initial testing stages, effusive beam of Argon gas was used as the target. Position and time information for Argon ions has been recorded, and the software for converting this data into momentum maps is nearly ready. Experiments for measuring momentum-resolved ionisation of atomic oxygen and for studying the kinetic energy distribution of fragments arising from molecular break-up will begin soon.

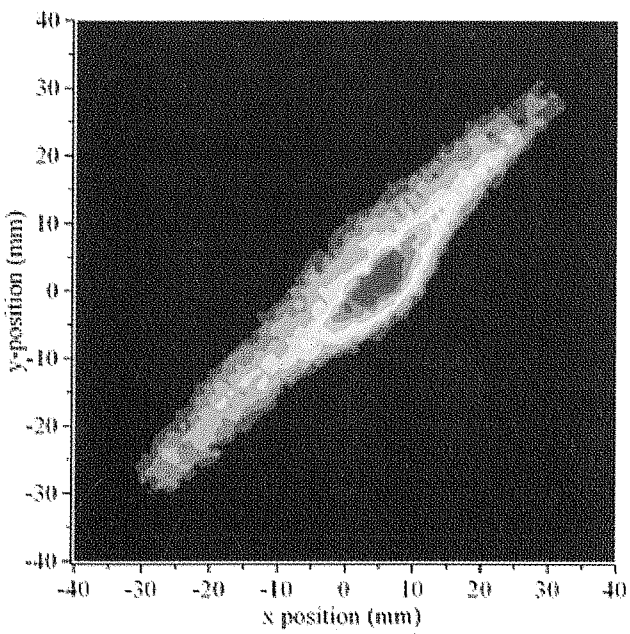


Fig. 6.6 : An image of the ion track created by the passage of electron beam in the new RIM spectrometer. The red spot close to the centre corresponds to high countrate arising from the overlap of the electron beam with an effusive beam of CO2.

(Bhas Bapat, V. Sharma, D. Kothari and R. K. Singh)

Multiple Ionization Cross Section Measurements of Argon using INDUS-1 Synchrotron

The collaborative program between PRL and the Centre for Advanced Technology (CAT), Indore for doing gas phase photoionisation experiments at the INDUS-1 Synchrotron (**Fig. 6.7**) has taken off. First re-

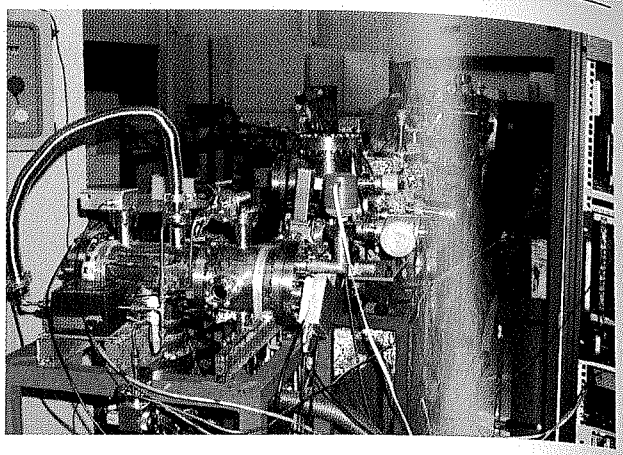


Fig. 6.7 : The experimental station of the PRL-SUS collaborative experiment at the INDUS TGM beamline.

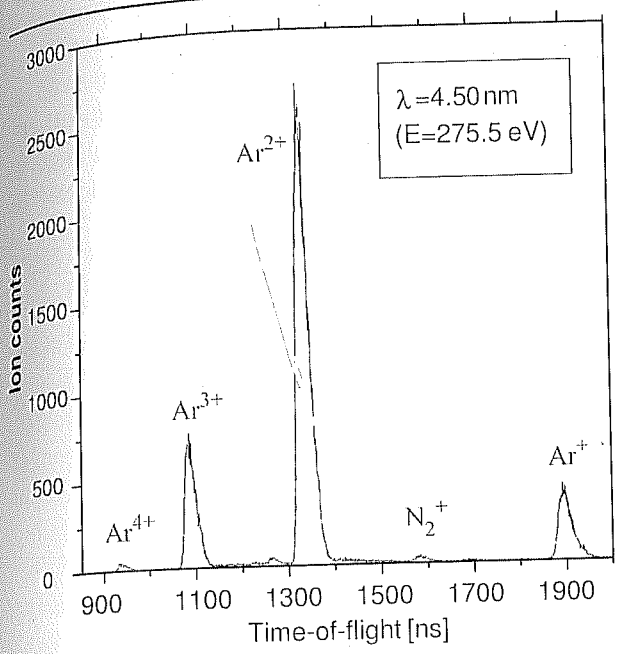


Fig. 6.8 : A time-of-flight mass spectrum of multiply charged Argon ions observed at the INDUS TGM experimental station.

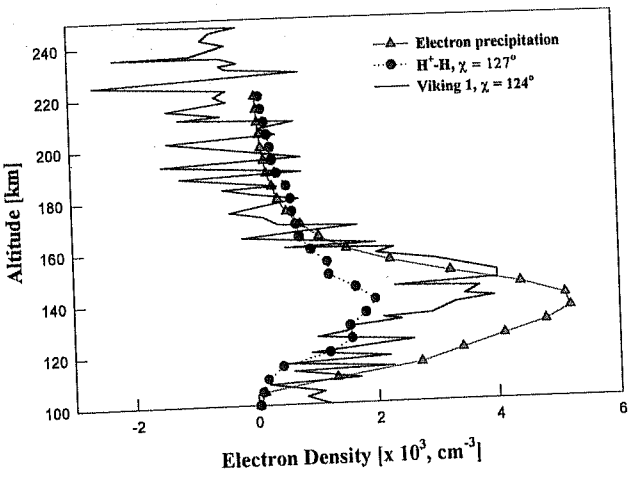


Fig. 6.9 The electron density profiles observed in nighttime by Viking 1 at solar zenith angle 124°. The calculated electron density at solar zenith angle 124° due to precipitation of solar wind electrons and H^+-H are also plotted.

sults on multiple ionisation of Argon were obtained in February 2004. Charge states as high as Ar^{4+} were detected, and a strong dependence of the relative cross-sections of various charge states on photon energy was observed (**Fig. 6.8**) Our observations are in agreement with previously published data. Efforts are on to begin a new set of experiments for studying molecular photofragm-entation and non-dipole effects in the angular distribution of photoelectrons from ionisation of noble gases.

(R. K. Singh, B. Bapat, K.P. Subramanian, D. Kothari, V. Sharma, A. P. Gohil and I. A. Prajapati)

Planetary/Cometary Atmospheres

Solar wind Electron Precipitation in the Nightside of Mars at Terminator Region

The nightside ionosphere of Mars was observed by Mars 3, 5 and Viking 1, 2 during low solar activity period. From the analysis of these measured data it appears that sometimes ionospheric peaks were not visible while at other times, two or three prominent peaks were found at altitude ranges ~190-200 km, 160-170 km or 132-150 km which were produced by different physical processes. These processes are studied by making a model calculation. We have calculated electron density due to precipitation of solar wind electrons and proton-hydrogen H^+-H atom in the nightside ionosphere of Mars at solar zenith angle 127° In **Fig. 6.9**, these calculations are compared with the measurements made by Viking 1 in the evening.

This calculation suggests that major peak in the nighttime is obtained by precipitation of solar wind electrons. The peak for H^+-H impact ionization occurs at about 135 km. This source seems to be an important ionization process, which can also participate significantly in the nighttime ionosphere of Mars. However, the peak values for this source is smaller than the measurements and other calculations have been made by using the precipitation of solar wind electrons.

(**S.A. Haider** and S. P. Seth)

Lower Ionosphere of Mars

The chemistry of the lower ionosphere of Mars is studied below 100km using one dimensional model under photochemical equilibrium condition The primary ionization sources in the model are solar radiation and cosmic rays. The chemical model couples ion neutral, electron neutral, photo dissociation of positive and negative ions, electron photo-detachment, ion-ion and ion-electron recombination processes involving over 100 chemical reactions. The electron density is calculated using charge neutrality condition. This calculation shows the chemical composition and chemistry in detail, indicating that Mars should have D-region at about 30 km due to high efficiency of the electron attachment to O_x molecules, which entails that concentration of negative ions is higher than that of electron below 30 km. The hydrated hydronium ions H_30^+ (H_2O/n for n=1,2,3 and 4 dominates below 70 km and O_2^+ dominates above this altitude while negative ions $NO_2^-(H_2O)_n$ and $CO_3^-(H_2O)_n$ for n=1,2 are major ions below 30 km. Above this altitude, electrons play an important role in the lower ionosphere of Mars.

(S.A. Haider, Vikas Singh and V.R. Choksi).

The research activities of the Division encompass studies of a wide variety of natural processes pertaining to the solar system, earth's lithosphere, hydrosphere, biosphere and atmosphere. Selected activities are described below.

Different Precursors for Chondrules of Enstatite and Ordinary Chondrites

Chondrules are the silicate spherules of millimeter size that make up >50% by volume of the chondritic meteorites. Though it has been established that flash heating followed by fast cooling is the process that formed chondrules, the exact heating agent and their formation location are still unknown. Theories predict that chondrules formed in the nebula and later became part of their parent chondrites, and suggest that the precursors of chondrules are not the same as their parent chondrites. With the laser microprobe, we have investigated nitrogen isotopic systematics of individual chondrules from unequilibrated chondrites belonging to H (Tieschitz, Udaipur, Dhajala), L (Saratov), LL (Chainpur) and E (Parsa, Qingzhen) to understand the possible differences between the precursors of chondrules and their respective parent chondrites. In **Fig. 7.1**, $\delta^{15}N$ values of each chondrule is plotted against its N content. The fields covered by bulk meteorites are also shown. It is very clear that for E chondrites, $\delta^{15}N$ has the same range as the bulk, but for ordinary chondrites, they show a wider range. This clearly suggests that the precursors of chondrules from E and O chondrites are different, but those of E chondrites seem to match their parent chondrites.

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

Martian and Lunar Meteorite Studies

Martian and lunar meteorites provide us free samples from random locations of these solar system objects. These invaluable samples are the only direct way to carry out rigorous laboratory investigations about planet Mars and provide additional information about Moon. We have investigated the martian meteorite Y000593 and the lunar meteorite Y983885, both from the Japanese Antarctic collection, to learn about their cosmic ray exposure history and trapped noble gases and nitrogen.

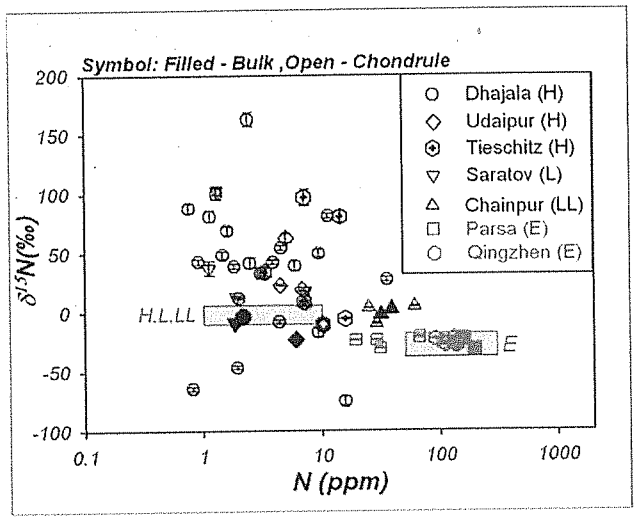


Fig. 7.1 : N contents and $\delta^{15}N$ (corrected for cosmogenic contribution) are plotted for individual chondrules. The ranges expected for the bulk ordinary (H,L,LL) and enstatite (E) chondrites are also indicated.

Y000593: We derived an exposure age of 11.9 ± 1.2 Ma for this nakhlite, similar to the other known nakhlites so far. But in trapped gases, there is negligible amount of Mars atmosphere and in this respect, Y000593 is more similar to Chassigny and is an ideal sample to look for interior gas components. We clearly identify an interior Ne component with ($^{20}Ne/^{22}Ne$) = 9.1 ± 0.7, different from Mars atmosphere, and an interior Ar component with a very low value for ($^{40}Ar/^{36}Ar$) ≤ 42, as compared to the value of > 40,000 for Earth. Such a low value for Mars is a clear indication of a low degree of degassing for the planet Mars. In addition to an interior N component with $\delta^{15}N \leq -15$ ‰ (similar to the already known Chassigny-S component) released during vacuum crushing, during step-heating, a clear second N component comprising 55% of total N and with $\delta^{15}N = 25$‰ has been released at 400°C combustion and is accompanied by 69% Xe of pure interior origin ($^{129}Xe/^{132}Xe$ = 1.039±0.008). Preservation of such diverse and primitive N components suggests that Mars interior remained frozen very early in its history.

Y983885: This lunar meteorite contains by far the largest solar gas concentration, except for severe losses

of He and Ne, due possibly to ejection related shock metamorphism. Cosmogenic gases are mostly produced during lunar surface residence. The most important result of this study is the identification of excess N of non-solar origin with $\delta^{15}N$ in the range of 30 to 50 ‰, in the low temperature fractions. This heavy N is not associated with trapped noble gases, clearly hinting at its source to be devolatalised N from either IDPs or comets that continuously bombard the lunar surface.

(J.P. Das, R.R. Mahajan and S.V.S. Murty)

Duration of Chondrule Formation and Solar Nebula Time Scales

Meteoritic chondrules are considered to be a product of high-temperature transient events taking place in the solar nebula. A determination of the time and duration of chondrule formation is an important step towards understanding the origin of chondrules. Analysis of chondrules from unequilibrated ordinary chondrites (UOC) and carbonaceous chondrites, using ^{26}Al as a chronological tool, suggests that the formation of the refractory Ca-Al-rich Inclusions (CAIs) in the solar nebula preceded chondrule formation and the large variation in the initial ($^{26}Al/^{27}Al$) ratio in the chondrules may be attributed either to differences in their formation age or to Mg isotope redistribution accompanying metamorphic processing. We have initiated a systematic study of UOCs of various metamorphic grades to get further insight in this regard. We show in **Fig. 7.2** the results of Al-Mg isotope systematics in one of the chondrules from the meteorite Adrar 003 analyzed by us. The data show presence of ^{26}Al in this Chondrule with a value of $(5.9 \pm 1.6) \times 10^{-6}$ for initial ($^{26}Al/^{27}Al$). Data for two other chondrules suggest similar initial ($^{26}Al/^{27}Al$) value, while several additional chondrules have lower initial of $\sim 10^{-6}$. The initial value in the chondrules are distinctly lower than CAIs ($\sim 5 \times 10^{-5}$) and confirms the later formation of chondrule relative to the CAIs. However, the high abundance of presolar grains in the Adrar 003 meteorite suggests that it experienced a low degree of thermal metamorphism and the observed spread in the initial ($^{26}Al/^{27}Al$) cannot be attributed to metamorphism. Our data strongly suggest an extended duration of chondrule formation in the

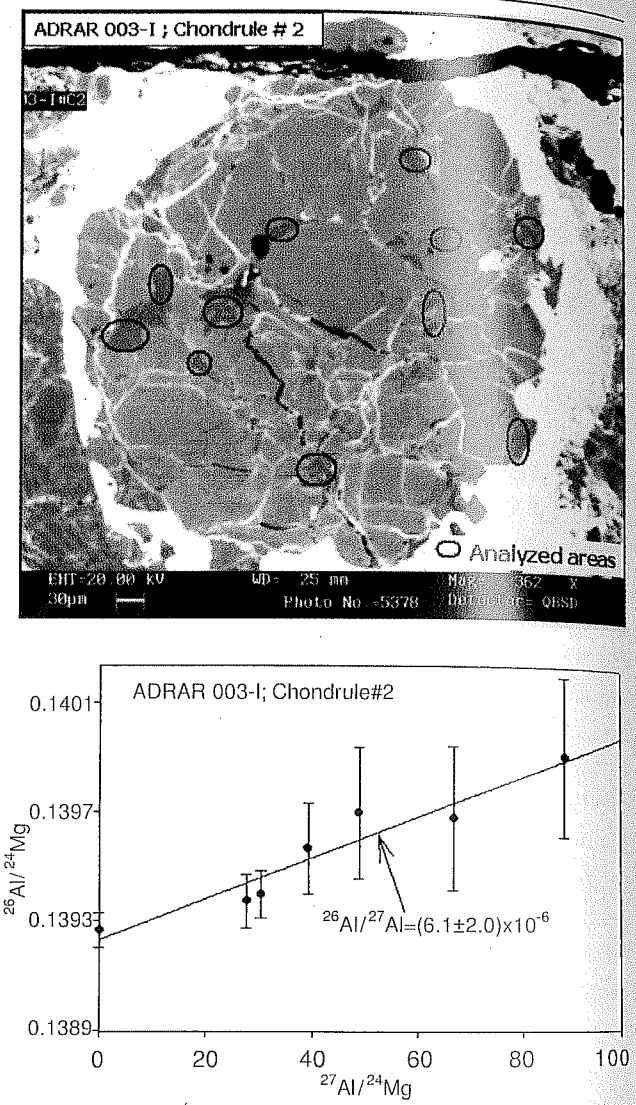


Fig. 7.2 : (a) Scanning electron photomicrograph of a chondrule from Adrar 003 analyzed for Al-Mg isotope systematics. (b) isotope data.

solar nebula. This will have important implications for nebular time scale and formation and accretion of smaller objects leading to formation of meteorite parent bodies and planetesimals in the early solar system.

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

Boron Isotopic Composition in the Protosolar Cloud

Analysis of bulk samples of meteorites and lunar rocks suggests a well-defined solar system boron isoto-

pic ratio. Even though non-solar boron isotopic composition at micro-scales within individual chondrules have been reported, an exhaustive study of chondrules from several types of meteorites failed to confirm this observation. The refractory Ca-Al-rich Inclusions (CAIs), whose formation in the solar nebula preceded chondrule formation, are ideal samples to check if the initial boron isotopic composition of the protosolar cloud differs from the reference solar system value. Data for Be-B isotopic systematics obtained by us and other groups are now available for 17 CAIs from five meteorites and show that the initial $^{11}B/^{10}B$ ratios at the time of formation of the CAIs are often lower than the reference solar system value. The $\delta^{11}B$ values in CAIs span the range from -66‰ to +22‰ with large uncertainties and yield a weighted mean value of about -15‰. The solar system reference $^{11}B/^{10}B$ ratio of ~ 4 represents a mix of two components; high-energy galactic cosmic ray produced component ($^{11}B/^{10}B$ ~ 2.5) and a low energy particle produced component enriched in ^{11}B. The variations in initial $^{11}B/^{10}B$ in CAIs may represent initial B isotopic heterogeneities in the protosolar cloud that did not persist up to the time of chondrule formation. Such heterogeneities may represent admixture of varying amount of boron produced by low-energy particle interaction added to the protosolar cloud at different epochs during its lifetime.

(J. N. Goswami)

Chemical and Cosmogenic Records in Recently Fallen Indian Meteorites

We studied three new meteorites out of which two are fresh fall and one of them is a find. One of the falls took place in Orissa at Kendrapara on September 27, 2003 and another in Muzzafarnagar district of U.P. on November 4, 2003. *Kendrapada meteorite* fall was a shower, which has fallen in various districts of Orissa. It belongs to the ordinary class of chondrites (H-5). The activities of cosmogenic radionuclides (^{7}Be, ^{22}Na, ^{26}Al, ^{26}Mn, $^{56,57,58,60}Co$) appear to be normal. The *Muzzafarnagar meteorite* was a single fall and was studied for the various cosmogenic nuclides as mentioned above which have been found to be normal. The *Aradki Meteorite* is a find, recovered from a canal site in the district Sri Ganganagar (Rajasthan). We detected the signature of long lived cosmogenic ^{26}Al (half life: 0.73Ma) only. It seems to belong to the rare group of primitive carbonaceous chondrites, which might be the largest meteorite of this type recovered from Indian soil.

(N. Bhandari, A.D. Shukla, P.N. Shukla and K. M. Suthar)

Geochronology of the Dharwar Craton

The Dharwar craton in southern India is one of the prominent Archean crustal block within the Indian shield. We have determined ^{207}Pb-^{206}Pb ages of zircons from the various lithounits of this craton to reconstruct its geochronological evolutionary history during the early Archean. We have focused our attention on the eastern block for which very little data are available at present. Five samples of metasediments, two quartzites and three metapelites from the eastern Dharwar block and three metasediments from the western Dharwar block were analyzed. Detrital zircons from the western block have formation ages in the range 3.0 to 3.5 Ga that overlap with ages reported earlier. Our data also suggest similar antiquity for detrital zircons in metasedimentary samples from the eastern block with ages covering nearly the same time span. The zircon ages for the eastern block are much older than anticipated from previous studies that suggested this block to be primarily a product of crust formation during early Proterozoic. We have also analyzed zircons from orthogneissic enclaves within the younger granitoids from the eastern block and obtained age ranging from 3.0 to 3.3 Ga, that are also similar to the ages of gneissic rocks from the western Dharwar block. Our results suggest that crust-forming events leading to the formation of the eastern Dharwar block started much earlier than proposed in previous studies.

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

Geochemistry of Volcanism along Nazca Ridge and Easter Seamount Chain

Study of the Nd-Pb-Sr isotopic, trace element, and major element characteristics of lavas from the Nazca

Ridge and Easter Seamount Chain east of Salas-y-Gomez (SYG) Island provides insight into the nature of the Easter-SYG hotspot source through the last 30 Myr. Major element analyses of glasses and whole-rocks from seamounts located between 17° 15.64'S, 78° 10.01'W and 19° 9.72'S, 79°38.99'W reveal that most are moderately evolved, transitional to moderately alkalic basalts (MgO = 4-7 wt%, TiO_2=2-4 wt%, K_2O=0.5-1.65 wt%). Incompatible element concentrations cover a wide range, from normal mid-ocean-ridge type to alkalic ocean-island type (OIB). Most of the seamounts we sampled are composed of OIB-type lavas, indicating a normal hotspot style of magmatism. Initial Sr, Nd and Pb isotopic ratios for most of the lavas define two categories: (1) N-MORB-like and transitional basalts ($^{206}Pb/^{204}Pb$= 18.709, $^{87}Sr/^{86}Sr$= 0.70267, ε_{Nd} = +8.6) and (2) incompatible-element-enriched MORB-like to strongly alkalic OIB ($^{206}Pb/^{204}Pb$= 19.402-20.012, $^{87}Sr/^{86}Sr$= 0.70320-0.70389, ε_{Nd} = +2.8 to +5.8). The Pb, Nd, and Sr isotope arrays are co-linear with those for southern East Pacific Rise MORB and OIB from relatively recent products of the Easter-SYG hotspot, indicating that the same end-members have been involved for the last 30 Myr: a high ε_{Nd}, low $^{87}Sr/^{86}Sr$, low $^{206}Pb/^{204}Pb$ MORB source and a low ε_{Nd}, high $^{87}Sr/^{86}Sr$, high $^{206}Pb/^{204}Pb$ hotspot source. The hotspot end-member is isotopically similar to the most commonly observed mantle component known as the "C" component. East of SYG, the lack of any geochemical gradient along the chain indicates that there has been no systematic change over time in the proportions of the end-members involved.

(**Jyotiranjan S. Ray** and J.J. Mahoney)

Stable Carbon and Oxygen Isotopic Compositions of Indian Carbonatites

Stable C and O isotopic compositions of carbonatites are results of fractionations caused by various magmatic and post-magmatic processes during the carbonatite generation and evolution. Our critical examination, using various theoretical models, of the available stable isotopic data from Indian carbonatites, which span in age from Precambrian (~2.4 Ga) to Cretaceous (65 Ma), revealed the following important information. (1) The average and mode of $\delta^{13}C$ distribution in Indian carbonatites (~ -4 ‰) are higher than global average; (2) the primary (unaltered) variations are found to be results of either batch crystallization under plutonic conditions as observed in Hogenakal and northeastern Indian carbonatites or fractional crystallization from CO_2+H_2O fluid rich parent magmas as observed in rest of the carbonatites; (3) the secondary (altered) isotopic variations in all the carbonatites are apparently results of low temperature alteration by either meteoric water or CO_2 bearing aqueous fluids. The estimated $\delta^{18}O$ values of the mantle sources of Indian carbonatites (5.3 - 7.5 ‰) show the expected normal upper mantle signatures, but the $\delta^{13}C$ values appear to be more variable (-6 to -3.1 ‰). The younger carbonatites (<107 Ma) in particular appear to have derived from ^{13}C enriched (plume?) sources. A combined scrutiny of $\delta^{13}C$ and $^{87}Sr/^{86}Sr$ data (**Fig. 7.3**) suggests that Indian carbonatite were derived from large-ion-lithophile element enriched mantle sources and the enrichment probably took place some time in Archean (~ 2.4 Ga ago). We suggest that the Indian sub-continental mantle, which got metasomatized with fluids from subducted oceanic crusts around that

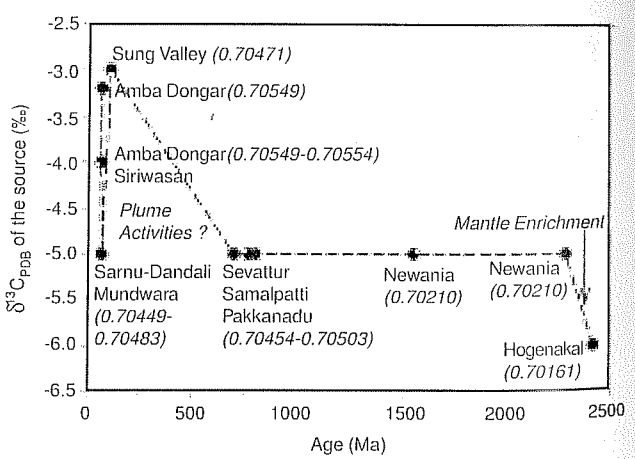


Fig. 7.3 : Model estimated $\delta^{13}C_{PDB}$ of the mantle sources for Indian carbonatites versus their emplacement age. The initial $^{87}Sr/^{86}Sr$ for the carbonatites (same for theirs sources) are given in the brackets next to their names.

time, has remained as a continuous source for these carbonatites.

(Jyotiranjan S. Ray and R. Ramesh)

Recycled Nitrogen in Lower Mantle

Knowledge of the nitrogen components in different terrestrial reservoirs is very essential for a proper understanding of the evolution of this most prominent atmospheric constituent, from the accretion stage of the Earth. Our earlier work based on MORBs has clearly shown that surface N has been recycled into the upper mantle (UM) and the pure UM end member of $\delta^{15}N$ is ~ -15‰. No credible information so far exists regarding the composition of nitrogen for the lower mantle (LM). We have taken up the study of carbonatites (supposedly of LM origin) of different ages and geological settings from within India, to investigate this aspect. We have separated carbonate, apatite and magnetite and employed vacuum crushing (VC) and pyrolysis (P) techniques for gas extraction and studied nitrogen and noble gases. Isotopic signatures ($^{20}Ne/^{22}Ne$) and ($^{129}Xe/^{132}Xe$) of trapped noble gases clearly establish the occurrence of mantle gases and those of ($^{21}Ne/^{22}Ne$) and ($^{40}Ar/^{36}Ar$) fall in the range of LM values. Of particular significance are the very different values of N contents, $\delta^{13}C$ and ($N/^{36}Ar$) for VC and P for apatite mineral separates. While VC yielded only a small amount of N (< 5%) with light isotopic signature ($\delta^{15}N$ < - 20‰) and low value for ($N/^{36}Ar$), the pyrolysis yielded large N content, positive $\delta^{15}N$ (≥10‰) and a high ($N/^{36}Ar$) ratio. A straight forward interpretation of these data suggests that there are two trapped N components in the apatites, a light N that exists in gas phase and accompanied by LM type Ar and hence of lower mantle affinity, and a second N component that is in solid speciation (inorganic form), not accompanied by noble gases and having positive $\delta^{15}N$. This N component represents nearly pure recycled component. A very light LM signature and definite presence of recycled N component with $\delta^{15}N$ ~ +15‰ in the LM are clearly shown by our results. Ignoring the possible presence of the heavy recycled N component is the reason for the earlier literature value of $\delta^{15}N$ ~ + 3‰ for the LM nitrogen.

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

Palaeovegetational Reconstruction in Late Miocene Based on Early Diagenetic Carbonate Cement from Indian Siwalik

Change in carbon isotope ratio of soil carbonates from Siwalik sediments has been used to show the transition of vegetation from C3 type to mixed C3-C4 type during the late Miocene period. However, scarcity of soil carbonate nodules in Indian Siwalik sections prevents accurate reconstruction of the timing and nature from C3 to C4 transition. It is of interest to check if the carbon isotope ratio of early diagenetic carbonate cement from sandstones can be used since the cement is derived from shallow groundwater which is in isotopic equilibrium with the plant derived CO_2. Carbon isotope ratio of the cement samples shows that at around 9 Ma, the vegetation was of C3 type. The ratio increased after 9 Ma indicating appearance of C4 plants. By around 7 Ma C4 plants dominated the ecosystem. This corroborates the earlier results from the Pakistan Siwalik.

(S.K. Bhattacharya and P. Sanyal)

Stable Isotopic Studies of Palaeosols from Upper Siwalik of Himachal Himalaya

Stable isotopic studies of the palaeosols from middle and upper Siwalik sections from Pakistan and Nepal regions were done by Quade J. and Cerling T.E. (1995) to infer palaeoclimate of these regions during early and late Miocene. We extended this study to the upper Siwalik of Himachal Himalaya, India. Carbon isotopes in palaeosol carbonate nodules and associated organic matter indicated an abrupt transient of C3 vegetation dominance around 4 Ma in the general trend observed of C4 ecological dominance from 8 Ma to 3 Ma. We attribute this observation to the higher monsoonal intensity around 4 Ma, as the greater moisture availability would lead to an abrupt transient of C3 vegetation

dominance in this region. And this is very well supported by other studies of *G. bulloides* abundances from DSDP core from Arabian sea and that of grass pollen abundances on the land. Time for sedimentary section studied was estimated from magnetostratigraphy and was checked and supported by Ar-Ar dating of a tuff of bed from Upper Siwalik section from Jammu.

(**P. Ghosh, J. T. Padia** and R. Mohindra)

Southern Margin of Thar

Studies on the Aeolian and fluvial sequences of the Southern Thar in the Orsang and the Mahi basin enabled a reconstruction of climate variation over the past 100 ka. Sediment architecture, textural analysis and luminescence dating indicated the presence of meandering rivers during the last interglacial stage indicating stronger monsoon conditions, a shift from meandering to braided river pattern during period 100-60 ka indicated weaker monsoon conditions with enhanced seasonality. The meandering systems established again after 60ka and persisted till 30ka. This along with regional floodplain aggradation and pedogenseis indicated stronger monsoon conditions. The monsoon weakened after 30 ka and eolian sedimentation at around 20ka indicates significantly weakened monsoon around the glacial maximum. Post 11 ka a regional landscape stability and a northward shift in dune forming climate is also seen. A regional tectonic activity that modified the courses of rivers was dated to 30 –11 ka age bracket.

(N. Juyal, A.K. Singhvi and **L. S. Chamyal**)

Chronology of Neotectonic Events in Kachhch and Their Implication for Recent Seismicity

Consequent to continent-continent collision and flexing of the Indian lithosphere, the paleo-rift basin of Kachchh (Kutch) in western India experienced several tectonic episodes along the major E-W faults. The 2001 Bhuj earthquake was the most recent evidence of continued seismicity along Kutch Mainland Fault (KMF). We attempted to create a record of long term seismicity by dating tectonically caused changes in the landscape features such as river terraces and the incision of river laid sediment in the northern hill range along KMF using blue green stimulated luminescence (BGSL) method. Optical ages on Quartz mineral separates provided evidence of bed rock incision during 12 ka to 5 ka followed by a phase of aggradations between 5 to 0.5 ka. Another incision event dated to 500a is also seen. Thus two episodes of uplift, at 12 ka and 500a occurred and imply rates of incision of ~1.5 mm/a on the bedrock terrace during 12 to 5ka, and 9.0mm/a during the past 500 ka on valley fill terraces. Recent geodetic measurements since 2001 have provided an uplift rate of 12mm/a in eastern KMF and this implies an increase in uplift rate during the past 500 years. Increasing deformation at the eastern limits of KMF has thus resulted in the right lateral thrust faulting on the south dipping South Wagad Fault. This resulted in the Bhuj 2001 earthquake event.

(**N. Juyal, G. Mathew, J. T. Padia, A.K. Singhvi** and R. V. Karanth)

Chemical Weathering of Eastern Himalaya

Studies on erosion rates of various basins of the Brahmaputra have been completed. The result for the Eastern Himalaya shows that the erosion rate in the Eastern Syntaxis is as high as 14 mm y^{-1}, similar to the reported exhumation rate for this region. The erosion rates for the Tibet, the Himalaya and the Mishmi Hill basins are much lower, 0.1, 2.1 and 2.3 mm y^{-1} respectively, similar to those obtained for these regions based on cosmogenic isotopes. The chemical weathering for the eastern Himalaya is also high resulting from higher runoff and high physical erosion of the region. Major ion and $\delta^{13}C$ of DIC indicates that about half of the cations in the Brahmaputra system are derived from silicates, same as that for Sr.

(S. K. Singh)

Chemical Weathering of Deccan Traps

As a part of our investigations on chemical weathering of Deccan Traps, $\delta^{13}C$ measurements were carried out in dissolved inorganic carbon (DIC) in twenty rivers to identify the sources of DIC and their mixing proportions. $\delta^{13}C$ value ranges between – 8.5‰ to –20.7‰, with eleven out of them having $\delta^{13}C$ in the range

of −18.7 ± 2‰, indicating exclusive silicate weathering with soil CO_2 from C3 vegetation. Others show higher $\delta^{13}C$ values, − 8.5‰ to −15‰, indicating mixing of DIC from silicate and carbonate end members. The $\delta^{13}C$ of DIC shows strong linear correlation with $1/(HCO_3)$ (r_2=0.82) and Si/HCO_3 (r_2=0.80) with intercepts (−9.6‰ and −8.9‰ respectively), similar to that calculated for $\delta^{13}C$ from carbonate weathering with C_3 soil CO_2.

(S. K. Bhattacharya, A. Das and S. Krishnaswami)

Dissolved Uranium and $^{234}U/^{238}U$ in the Yamuna and the Chambal rivers

Concentrations of dissolved uranium and $^{234}U/^{238}U$ activity ratios were measured in the Yamuna headwaters in the Himalaya and the Chambal river system in the plains to determine their sources and to study weathering and mobility of uranium in these watersheds. The dissolved uranium in the Chambal river system ranges from 0.2 to 1.74 $\mu g\ L^{-1}$, whereas in the Yamuna, it varies from 0.09 to 3.61 $\mu g\ L^{-1}$. The high concentration of uranium in Hanuman Chatti is derived from weathering of the Higher Himalayan Crystalline series (HHC) and associated accessory minerals and uranium mineralized zones. The $^{234}U/^{238}U$ activity ratios in the Chambal watershed range from 1.15 ± 0.05 to 1.67 ± 0.04 and in the Yamuna it varies from 0.95 ± 0.03 to 1.56 ± 0.07. The high $^{234}U/^{238}U$ activity ratios in the Yamuna system are in its tributaries from the lower reaches, the Amlawa, Aglar, Bata, Tons and the Giri. This is due to weathering of metamorphosed carbonates and/or through groundwater inputs with significant uranium isotopic disequilibrium. It is estimated that ~9 and ~12 tons of uranium are transported annually in dissolved form from the Yamuna river at Batamandi (the foothills of the Himalaya) and the Chambal river at Udi respectively. This study confirms that uranium weathering rate in the Himalaya is far in excess of the global average value of ~0.08 kg $km^{-2}\ y^{-1}$.

(S. Krishnaswami, R. Rengarajan and M. M. Sarin)

New production in the Bay of Bengal

New production has been estimated in the Bay for two seasons, pre and post monsoon. The overall total production during post and pre monsoon average around 4 and 9 mmolN $m^{-2}d^{-1}$. The new production averages around 3 and 6 mmolN $m^{-2}d^{-1}$ for post and pre- monsoon respectively. The average new and total production during post monsoon are higher for open ocean stations (3 and 4.5 mmol N $m^{-2}d^{-1}$) than coastal (2 and 3.5mmol $Nm^{-2}d^{-1}$) stations. The average new and total production during pre monsoon are higher for coastal stations (9 and 11 mmol N $m^{-2}d^{-1}$) than open ocean stations (4 and 6 mmol N $m^{-2}d^{-1}$) stations. Conservative estimates suggest the f-ratio(ratio of new to total production) to be around 0.7 and 0.6 for pre and post monsoon respectively. These results are the first estimates of new production in the Bay of Bengal. The total production estimates presented here are comparable to those reported for the Bay of Bengal during recent study by ^{14}C technique. The higher values at open ocean locations during post monsoon may be due to the availability of nitrate due to the churning up of the ocean caused by cyclonic activity. The reduced stratification of the upper layer in the Bay during 2002 might have also helped in bringing nutrients to the surface. The high new and total production at coastal locations during pre monsoon season may be due to poleward flowing East India Coastal Current (EICC) which might bring nutrients for the planktons.

(S. Kumar and R. Ramesh)

Aerosol Chemistry over the Bay of Bengal

A large set of observations was made over the northern Bay of Bengal to characterize the chemical composition of atmospheric aerosols during the late NE- and SW-monsoon seasons. The Bay of Bengal is an ideal area to study the atmospheric constituents associated with crustal and anthropogenic emissions from south and south-east Asia. A characteristic feature of the aerosols of February 2001 and 2003 is the high abundance of SO_4^{-2} (average 5.2 ± 2.3 $\mu g\ m^{-3}$) supplied from anthropogenic sources. In contrast, Na^+ and Cl^-(average 75%) is dominant during SW-monsoon (September 2002). The results also show significant temporal variation and co-variance among Al, Fe, Ca, Mg and Mn suggesting their common crustal source and transport pro-

cess. The enrichment factors for Cd, Pb and Zn exceed 100 (based on crustal Fe) attributable to their anthropogenic supply (**Fig.7.4**).

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

Synoptic Hydrology of India from the Data of Isotopes in Precipitation

Using seasonal isotopic data of precipitation from the IAEA/GNIP network (http://isohis.iaea.org) over and around the Indian region large scale synoptic hydrology of India was investigated. It was shown that, primary oceanic vapor influx areas along west and east coasts both during SW summer and NE winter monsoons are characterized by 'd-excess' in the 8-12‰ range. Due to continued aridity even during the period of summer monsoons, the rain shadow zone of Western Ghats, parts of southeast coast, central and northwest India, show clear indication of evaporation from falling raindrops in the form of a belt of low (<8‰) 'd-excess'. The region over Bangladesh and the eastern states of Tripura, Manipur and eastern Myanmar show high (>12‰) 'd-excess' values in precipitation for most of the year except at the beginning of the May. From August onwards, the area covered by this high 'd-excess' region progressively increases and spreads westwards indicating evaporative recycling of vapor from the very large area of wetlands and soil moisture during the monsoon and post monsoon seasons. Another region of persistent recycled vapor of land origin lies over Afghanistan and Pakistan. It spreads to Jammu & Kashmir during winter-spring under the influence of Western Disturbances as seen clearly in the low $\delta^{18}O$ (-14‰ to -6‰) values of precipitation. This spread of land derived vapor during winter-spring is not so clearly seen in enhanced 'd-excess' over Jammu & Kashmir as evaporation from the falling raindrops reduces their high 'd-excess' to ~10‰. The lowering of $\delta^{18}O$ values in May seen in eastern India and Bangladesh indicates onset of vapor influx from the northern BOB. This is also indicated by decrease in 'd-excess' value of precipitation from the previous season (from >12‰ to ~10‰).

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

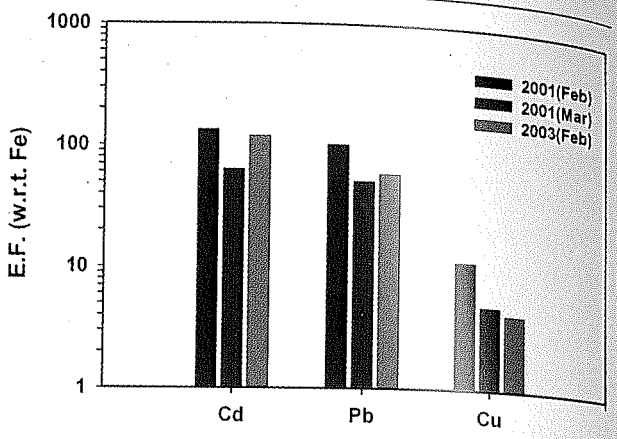


Fig. 7.4 : Enrichment factors for trace metals

High Fluoride in Groundwater in India Linked to Evaporation Before Recharge

Regions with high fluoride concentration in groundwater largely overlap the arid parts of the world and in India also. Isotopic investigations of ground waters have shown a very significant evaporation related modification of isotopic signal of precipitation in large parts of the India, where the ground waters are enriched with respect to the precipitation in δ^{18} and show lower values of 'd-excess'. There is minor to significant evaporation of the precipitated water before groundwater recharge. Areas with low values of 'd-excess' broadly show high fluoride concentration in groundwater suggesting pre recharge concentration of dissolved fluoride in soil water due to evaporation. A compilation of the data of Tritium tagging studies for groundwater recharge estimation also indicated low values of recharge in these areas.

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

Isotopic Composition of Methane from Paddy Fields and Atmosphere of Ahmedabad

To determine $\delta^{18}C$ of methane arising from paddy fields of Gujarat and compare them with our previous data from Andhra Pradesh six samples of air were collected during the paddy-growing season of August to November, 2003. The samples were processed using

the "Methane Extraction system" developed at PRL for converting methane to carbon dioxide. The $\delta^{18}C$ of purified CO_2 (~1 cc) was measured using GEO 20-20 mass spectrometer. The values vary from -46 to -59 ‰ (relative to PDB) similar to that from paddy fields of Andhra Pradesh (-46 to -60‰).

(S.K. Bhattacharya, R.A. Jani and D.K. Rao)

Dry and Wet Deposition of Atmospheric Nitrogen at Ahmedabad

The temporal variation in the atmospheric concentrations and deposition fluxes (dry and wet) of major Nitrogen species (NH_4^+ and NO_3^-) have been determined for a three-year period, 2000-2002, at Ahmedabad (23°03'N, 72°38'E). The concentrations of NH_4^+ and NO_3^- varied from < 3 to 220 and 1.3 to 115 $\mu eq\ l^{-1}$, respectively, in individual precipitation events. Their concentrations in the bulk-aerosols (collected on tissuquartz filters) show similar variations (NH_4^+: <0.03 to 0.91; NO_3^-: 0.29 to 4.03 $\mu g\ m^{-3}$) with higher concentrations during January-March and October-December. The average wet-deposition fluxes of NH_4^+ is ~200 mg $m^{-2}y^{-1}$ considerably higher than its dry-deposition flux ~20 mg $m^{-2}\ y^{-1}$. In contrast, the deposition of NO_3^-, during the 3-years, averaged ~300 mg $m^{-2}\ y^{-1}$ via the wet-phase and ~150 mg $m^{-2}\ y^{-1}$ via dry deposition (**Fig.7.5**). Our results indicate that the dry and wet-depositions of NO_3^- accounts for ~ 70% of the deposition of inorganic-N. Wet-deposition of NH_4^+ dominates (~90%) its atmospheric removal.

(N. Rastogi and M.M. Sarin)

Constraints on the Erosion History of the Tibetan Plateau since the Last Interglacial from the first Studies of Cosmogenic ^{10}Be

The cosmogenic ^{10}Be exposure histories of in-situ bedrock surfaces from the Tibetan Plateau indicate low erosion rates of < 30 mm/ka in southern and central Tibet during the last interglacial-glacial cycle that contrast strongly with unusually rapid erosion rates (60 to 2000 mm/ka) from the Kunlun of northern Tibet during

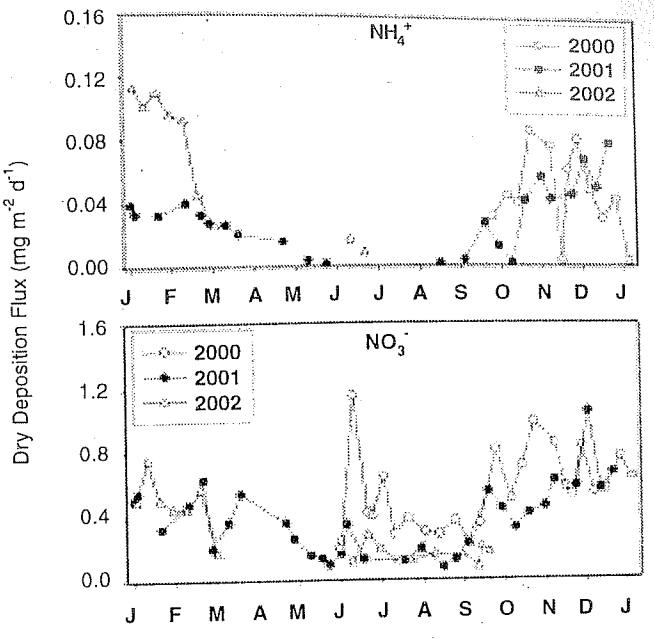


Fig. 7.5 : Temporal variations in dry-deposition fluxes of NH_4^+ and NO_3^-

the Holocene comparable with published values from the Himalaya. These results suggest that whereas the southern and central plateau had reached a stable elevation prior to the last interglacial, the northern margin of the plateau was subject to intense tectonic activity during the Late Pleistocene-Holocene. By comparing apatite fission-track ages with cosmogenic data, erosion rates in southern Tibet appear to be decelerating since the Miocene, whereas in the Kunlun, erosion rates have accelerated over the same timescale. These findings indicate that over much of the high plateau erosion rates are exceptionally low and therefore the sources of detritus carried by the great Asian rivers that rise in Tibet lie overwhelmingly in bedrocks at lower altitudes. This study illustrates the potential of cosmogenic studies for unraveling the most recent phase of the erosion/exhumation history of orogenic belts that can not be resolved by either Ar-isotope or fission-track thermochronometers.

(**Devendra Lal**, N. B. W. Harris, Kewal K. Sharma, Weiquan Dong, Marc W. Caffee, Z.Y. Gu, Z. L. Ding, Tungsheng Liu and A. J. T. Jull)

Estimation of Low-energy (10-200 KeV) gamma-ray fluxes from the Moon

The Chandrayaan-1 mission will carry an instrument to measure the gamma-ray fluxes from the Moon in the energy-region 10-200 KeV. The expected flux of gamma-rays from the Moon in this energy region that will be primarily due to U-Th decay series and (n,γ) reactions involving some of the rare earth elements, has been estimated. One of the nuclide of prime interest is ^{210}Pb that may be used as a proxy for studying transport of volatiles on the lunar surface.

Solar X-ray and Fluorescence Emission from Lunar Surface

Preliminary calculations of solar X-rays spectra for the period of solar maximum appropriate for the proposed Indian Lunar mission are made using an analytical model for continuum emission of an optically thin plasma whose electrons have a Maxwellian energy distribution in the wavelength range 1-1000 Angstrom and temperature in the range 0.01-100 million degree kelvin. The predicted X-radiation will be used further in calculating x-ray fluorescence emission from various lunar terrains having different chemical compositions during different phases of the solar cycle.

Study of Energy-Response of Cd-Zn-Te (CZT) Detector

Hardware and software subsystems have been developed for ground-based operation of a Cadmium-Zinc-Telluride (CZT) array detector of $16cm^2$ area. Integration and testing of these sub-systems have been carried out to evaluate the detector response at room temperature. Additional study of background and gain of individual pixel in shielded and low-temperature environment is under way. CZT array will be used in the high energy X-ray (HEX) payload to be flown in Chandrayaan-1 mission. We have also used GEANT4, a Monte Carlo simulation tool kit developed at CERN, to simulate the energy response of a CZT detector to ^{241}Am, ^{57}Co and galactic cosmic ray protons, solar protons, and secondary neutrons. The simulated data for the IMRAD CZT detector are found to be very similar to the experimentally determined response to ^{241}Am.

Reflectance Spectroscopy of Rocks and Minerals

Reflectance spectroscopy of lunar and terrestrial minerals were carried out to study the effect of various parameters such as mineral mixture, presence of opaque minerals and viewing geometry on reflectance values in the visible and near infrared region of the electromagnetic spectrum using a reflectance spectrometer at the Space Applications Center (SAC) and the ALTA reflectance spectrometer at PRL. The change in reflectivity due to grain-size and maturity was clearly evident in the lunar samples.

Studies of Freshly Fallen Meteorite

Samples of the two recently fallen meteorites in Orissa (Kendrapara) and UP (Muzzafarnagar) were received from GSI, Calcutta. Studies of cosmogenic radioactivity, nuclear track and noble gas are currently in progress. Detail field studies combined with eye-witness report of the Orissa fall led to an estimation of its orbital parameters. Initial data for cosmogenic nuclides and nuclear tracks suggest it to be at least a meter-size object belonging to the ordinary chondrite group.

Planetary Astronomy

A couple of projects on observation of satellites and minor objects in the infra-red wavelengths were initiated. These include studies of Titan and Jupiter in the near infrared bands (J, H, K) and of asteroids in visible and IR bands using the telescope at Mt. Abu. These studies led to detection of H_3^+ molecule in Jupiter atmosphere and variation in IR emission from Titan's atmosphere that may be related to transient cloud phenomena.

(D. Dhingra, S. Harsha, A.V. Jirgale, Goerge Koshy, M. Shanmugam, M. Shivakumar, K.B. Smart, N. Srivastava, P.O. Suresh, N. Verma, D. Banerjee, N. Bhandari, S. Chandrasekhar, J.N. Goswami, S. A. Haider, H.S. Mazumdar)

Facilities

Computer Centre

Computer Centre is equipped with IBM RS-6000 SP Computer having 16 processors and 32GB RAM to cater for high computing needs of scientists. Centre also has high-end graphics station, IBM RS-6000 Model 270 with 4 processors. These machines are in addition to existing five IBM RS-6000/580 machines. To cater for the needs of scientists, POE has also been installed on RS6000/SP and RS6000/270 machines this year. All these machines are connected to our high-speed local area network (LAN) to provide easy, fast and reliable access to more than 200 PC's and few workstations distributed throughout the laboratory. Also, other centres at Udaipur and Abu are connected to the PRL LAN on 64 Kbps BSNL leased line. Thus full connectivity has been provided to users all the time from anywhere to the Main Campus, Thaltej, USO, and Mt. Abu. The Centre provides centralized virus free E-mails by automatically scanning all E-mails. Anti-Spam filter has been centrally installed to fight the Spam mails. The center also provides web enabled email service. Internet authorizations, monitoring and reporting functions have been added to have optimal usage of Internet bandwidth. Center also installed one high resolution, high-speed colour laser printer and two black and white laser printers, which provide high quality duplex laser printing to all PRL members over LAN.

Mathematical, numerical and visualization application software like IMSL, IDL, Mathematica, Data Explorer etc. have also been installed on the new computers to provide smooth transition and 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 is responsible for the collection development and processing for the libraries in all the four campuses of PRL – PRL Main Campus, Thaltej, Mt. Abu and Udaipur Solar Observatory.

The library collection, at present stands at 18,000 books and 29,000 bound volumes of journals, 552 audio visual (A-V) documents, 1600 reports and 3400 reprints of PRL authors. The library has added 171 books in English and 145 books in Hindi to its collection. It has fulfilled 332 ILL requests from other libraries and received 203 documents on ILL from other libraries. The library procured 9 articles from STN, which is a paid Document Delivery Service. About 1.70 lacs of photocopies were taken out from the in-house photocopying machine in this period.

Library homepage has been completely redesigned with lot many useful links like important institutes, universities, booksellers, publishers.

One more digital resource has been added to the library resources. IOP Archive and the PRL theses submitted by students have been put onto the web and can be accessed through the library homepage. ScienceDirect has been subscribed this year too. This allows access to 1100 Elsevier Journals. Out of 149 journals subscribed, 115 are available online.

The library staff also imparts training to the library trainees in the all the aspects of the library functioning.

Workshop

The Workshop provides support to the scientists and engineers of the laboratory in designing, planning and fabrication of a variety of mechanical components, mechanisms and systems for various scientific experiments. Workshop has range of machines that varies from a simple lathe machine to CNC lathe, milling, drilling, TIG welding machine for welding ferrous and non-ferrous metals etc.

Some of the major jobs completed during this year are listed below:

Gas Cell Chamber

The gas cell chamber for SMM project was designed & manufactured from S.S-304. The chamber uses

S.S pipe of 1.5 feet long of ϕ 2" , S.S flanges, KF couplings, and couplers. All components (flanges, couplers & pipe) were precisely welded with TIG welding machine. A copper coil of ϕ 6mm was wrapped & then brazed around the S.S pipe for cooling purpose.

New All Sky Imaging System to Study Gravity Waves and Plasma Depletions

This involves assembly of several precision components like Fish Eye Lens, Interference filter, Image Intensifier, C.C.D Camera and Front & Back coupling Optics in a box of size 2 feet length x 1.25 feet width x 1.5 feet height.

High Grade Stainless Steel Reaction Vessel

The job was manufactured from raw material of the size ϕ 8" x 10" length S.S Rod. Special care was taken while boring up to the inside depth of 10" with inside taper & internal radius. Dimensional as well as Geometrical tolerances were maintained within the limit of $\pm$0.05mm during the fabrication of the job. Buffing was made for the purpose of surface finishing. High Grade Stainless Steel Reaction Vessel was used for the preparation of Lithium Carbide.

Schottky Mixture Mounting System for Detector

Schottky Mixture Mounting Mechanism for SMM project was designed & fabricated. The 3D model was prepared on Mechanical desktop software. This job involved mounting of detector on a rotary table with good precision during assembling and mounting.

Electron Gun Housing

The job was designed and fabricated for SAP/AM for the purpose of mounting electron gun in vacuum chamber. Housing was made with a S.S tube, CF 63 flange & S.S couplers. KF- 40 flange was welded on the one end of the S.S pipe & aluminum threaded cap with slot was assembled on the other end. Vent holes were also machined on the periphery of S.S tube. All welding joints were made by Argon welding & complete assembly was fitted in to the vacuum chamber.

Gravity Corer

This job involved fabrication of outer PVC pipe of ϕ 4" x 10" long and inner pipe of ϕ 2" for PGS/DN group. At the end of outer pipe, a nose of brass material was coupled & also S.S fins were assembled with the nose for extracting mud.

Some other important work carried out in the workshop includes, Light shutter for the detector to block the stray light reaching the photo multiplier tube, S.S chamber for molecular beam apparatus, Drive for Gun moving system, Fabry Perot mount, A target mount holder and a movable platform for Laser produced plasma experiment, Optical mount for fine adjustment, Atmospheric Moisture Sampler, Fingers for metal extraction unit, Sheet and Structural fabrication work for various instruments.

Some precision works like Beam Ionizer, Sample Holders (Aluminum & G.I Pipe), Mesh Holder, Langmuir Probe Sensor, View Port Flanges For Laser Produced Plasma experiment etc were fabricated using CNC lathe machine.

Workshop also provides support to Mt. Abu Infared Observatory and Udaipur Solar Observatory from time to time apart from supporting the Thaltej Campus.

Engineering Services

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

The Site preparation works during the year under report were executed for the installation of sophisticated

research equipment, duly complying with all the special requirements. The major works undertaken during the year have been;

* The DG Set room at Udaipur–work completed.
* Canteen Renovation under progress.
* Renovation of Hostel block-1, nearing completion.
* Replacement of MS windows with Alm. Windows, under progress.
* Construction of staff quarters at USO, Udaipur, under progress.
* Construction of compound wall for PRL main campus.
* Vertical extension of chemistry building–under progress.
* Renovation of PDF quarters – Block C, work com-pleted.
* Fabrication & Installation of vertical 25Mtr high MS structural Antenna at thaltej campus for Ionosonde.

Honorary Fellows

Professor J.E. Blamont

Acad. V.L. Ginzburg

Professor A.M.J. Tom Gehrels

Professor D. Lal

Professor M.G.K. Menon

Professor U. R. Rao

Prof. P. Crutzen

Prof. K. Kasturirangan

Prof. A. Hewish

Academic Faculty

Academic Faculty

Name	Specialisation	Academic Qualification
Prof. G. S. Agarwal FNA, FASc, FNASc,FTWAS	Quantum Optics, Nonlinear Optics and Laser	Ph D Rochester Univ. (1969)
Prof. N. Bhandari FNA, FASc, FNASc	Planetary Physics	Ph D TIFR Bombay Univ (1967)
Prof. S. Krishnaswami FNA, FASc, FNASc, FTWAS	Aqueous Geochemistry and Nuclear Oceanography	Ph D TIFR, Bombay Univ. (1974)
Prof. A. R. Prasanna	General Relativity and Astrophysics	Ph D Poona Univ.(1970)
Prof. D. P. Dewangan	Atomic and Molecular Physics	Ph D Calcutta Univ. (1973)
Prof. J. N. Goswami FNA, FASc, FNASc	Solar System Studies (Pre - Solar Processes)	Ph D PRL, Gujarat Univ. (1978)
Prof. V. K. B. Kota	Nuclear Physics	Ph D Andhra Univ.(1977)
Prof. A. S. Joshipura FASc	Particle Physics	Ph D Bombay Univ. (1979)
Prof. A. K. Singhvi FNA, FASc, FNASc	Palaeoclimatology and Geochronology	Ph D IIT, Kanpur (1975)
Prof. S. K. Bhattacharya FASc	Isotope Geochemistry	Ph D PRL, Gujarat Univ. (1980)
Prof. V.B Sheorey	Theoretical Atomic Physics & Nonlinear Dynamics	Ph D Univ. College, London Univ (1968)
Prof. S. D. Rindani	Particle Physics	Ph D IIT, Bombay (1976)
Prof. Harish Chandra	Ionospheric Studies &	Ph D PRL, Gujarat Univ. (1970)
Prof. B. G. A. Rao	Spectroscopic Diagnostic in Astrophysical Plasmas	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)
Dr. U. C. Joshi	Star Formation, AGNS and Comets	Ph D Kumaun Univ. (1981)
Prof. P. Venkatakrishnan	Solar Physics	Ph D, Bangalore Univ. (1984)
Dr. R. E. Amritkar FASc	Nonlinear Dynamics & Chaos	Ph D IISc, Bangalore (1978)

Name	Specialisation	Academic Qualification
Dr. Utpal G. Sarkar	Particle Physics	Ph.D Calcutta Univ. (1984)
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. H. S. S. Sinha	Upper Atmospheric and Ionospheric Studies	Ph D PRL, Gujarat Univ. (1977)
Dr. N. M. Ashok	Infrared Observations	Ph D PRL, Gujarat Univ. (1983)
Dr. T. Chandrasekhar	Optical & Infrared Astronomy	Ph D PRL, Gujarat Univ. (1982)
Dr. A. Jayaraman	Atmospheric Aerosols and Radiative Studies	Ph D PRL, Gujarat Univ. (1985)
Dr. Hari Om Vats	Ionospheric Physics and Radio Astrophysics	Ph D PRL, Gujarat Univ. (1979)
Dr. S. V. S. Murty FASc	Isotope Cosmochemistry	Ph D IIT, Kanpur (1981)
Dr. A. K. Ambastha	Solar Plasma Physics	Ph D PRL, Gujarat Univ. (1981)
Dr. K. S. Baliyan	Atomic Physics & Atomic Astrophysics	Ph D Roorkee Univ.(1986)
Dr. Kanchan Pande	Geology, Geochronology	Ph D PRL, Gujarat Univ. (1990)
Dr. P. N. Shukla	Geochemistry	Ph D IIT, Kanpur (1977)
Dr. P. Sharma	Geophysics and Hydrology	Ph D PRL, Gujarat Univ. (1977)
Dr. J. R. Trivedi	Geochronology	Ph D PRL, Gujarat Univ. (1991)
Dr. J. Banerji	Laser Physics	Ph D City Univ.(New York)(1982)
Dr. Ashok K Singal	Radio Astronomy	Ph D TIFR, Bombay Univ.(1986)
Dr. D. P. K. Banerjee	Astronomy & Astrophysics, High Resolution Spectroscopy	Ph D PRL, Gujarat Univ. (1991)
Dr. K. P. Subramanian	Experimental Atomic and Molecular Physics	Ph D PRL, Gujarat Univ. (1987)
Dr. Syed Aftab Haider	Planetary and Cometary Atmospheres	Ph D Banaras Univ. (1984)
Dr. P. Janardhan	Radio Astrophysics	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. S.C. Tripathy	Solar Physics	Ph D PRL, Gujarat Univ. (1993)
Dr. Rajmal Jain	Solar Physics	Ph D PRL, Gujarat Univ. (1983)

Name	Specialisation	Academic Qualification
Dr. J. R. Bhatt	Astrophysics	Ph D PRL Gujarat Univ. (1992)
Dr. A. Lakshminarayan	Nonlinear Dynamics & Quantum Chaos	Ph D State Univ.,New York (1993)
Dr. H. Mishra	Strong Interaction Physics & Nuclear Astrophysics	Ph D, Utkal Univ. (1994)
Dr. R. Rangarajan	Particle Physics & Cosmology	Ph D, Univ. of California, Santa Barbara (1994)
Dr.P.K. Panigrahi	Field Theory	Ph D, Rochester Univ. (1988)
Dr. 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)