वार्षिक रिपोर्ट
ANNUAL REPORT
2006-2007

Diamond Jubilee Year
1947-2007

भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद
PHYSICAL RESEARCH LABORATORY, AHMEDABAD

वार्षिक रिपोर्ट

Annual Report

2006 - 2007

भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद

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Contents

1947

INTRODUCTION

Introduction

On November 11, 2006, Physical Research Laboratory (PRL), crossed an important milestone when it entered its sixtieth year. From an humble beginning in 1947, when Prof. Vikram A. Sarabhai established PRL to pursue research in cosmic rays and atmospheric sciences, PRL has taken great strides over the years and has etched its imprints on Indian Science, as the *cradle of space science* in the country. In addition, the laboratory has contributed significantly towards human resource development in the country. The alumni of PRL have shouldered major responsibilities and have played leadership roles in the development of India's space programmes of the country.

PRL continues to make pioneering research contributions in the broad areas of Space & Atmospheric Sciences, Astronomy & Astrophysics, Earth & Planetary Sciences and Theoretical Physics. A recent addition to this spectrum is Planetary Science and Exploration.

A major event during the year was the inauguration of the Diamond Jubilee Celebration of the laboratory by His Excellency the President of India, Dr. A. P. J. Abdul Kalam. The function was graced by a number of dignitaries, past and present staff members of PRL, invitees from research and educational institutions, and friends of PRL from India and abroad. A symposium on *"Recent Excitements in Science and Future Perspectives"* organized by the PRL Alumni Association on the eve of the Jubilee saw participation of a large number of alumni, including the first research scholars of PRL who completed their Ph.D during the early fifties. These functions were followed by a three day "Open-House" exhibition on PRL to show case its research activities. Over ten thousand School and College students and members of the public visited the exhibition. The Diamond Jubilee celebrations are continuing through the year and PRL is hosting several International Conferences and a series of Diamond Jubilee Public lectures.

This reports summarizes, significant achievements by PRL scientists, during the past year. An overview of some of the important results is described below.

An intensive observing campaign of the recurrent nova RS Oph that went into its sixth ourburst on 12 February, 2006 was conducted from the Mt. Abu observatory. This binary

system consists of a red giant star and a companion white dwarf. The observations led to the detection of a near-infrared shock wave resulting from interaction of the nova ejecta with the red giant stellar wind. The temporal evolution of the shockwave is broadly consistent with predictions of analytical models A relatively high mass of ~1.35 solar mass was inferred for the white dwarf, making it a potential candidate for a supernova.

Near-infra-red spectra in the H (1.4 micron) and K (2.4 micron) bands for 80 Asymptotic Giant Branch (AGB) and Post-AGB (PAGB) stars show that the equivalent widths of the CO (3-0) second overtone bands are better correlated with infra-red colors compared to the first overtone bands. Variability in the first overtone bands in a few PAGB stars indicates ongoing episodic mass loss in them.

A study of solar wind "disappearance events" that had their origins in active solar region highlighted the role of stable and unipolar outflows from the Sun in generating unusually long lasting density depletions in solar wind at 1 AU.

High resolution solar flare X-ray spectra in the energy range 4-20 keV observed by the Solar X-ray (SOXS) Payload on board GSAT-3 suggested that multi-thermal power laws and non-thermal components are needed to explain the observed features. This is in contrast to the previously considered isothermal approach.

Observation of "Doppler ribbons" along with H-alpha ribbons during the X17 flare of October 28, 2003 in the "super active region" NOAA AR 10486 suggest that this could be a manifestation of a pressure impulse striking the photosphere, following explosive evaporation in the chromosphere.

The indigenously built Solar Vector Magnetograph (SVM) was formally commissioned in February, 2007 at the Udaipur Solar Observatory. The Adaptive optics system (AOS) that is being developed in house, is nearing completion.

As a part of the Integrated Campaign for Aerosol, Trace Gases and Radiation Budget (ICARB), the scientists of Space and Atmospheric Sciences and Planetary & Geosciences Divisions measured aerosol properties and trace gases over the Bay of Bengal (BOB) and the Arabian Sea. Several important results suggesting a strong effect of convection on the vertical distribution of ozone in the troposphere over the BoB and MMS increasing abundence of mineral dust from north to south Arabian Sea were obtained.

Studies of mesospheric turbulence through simultaneous rocket-borne and ground-based radar observations led to detection of strong turbulence in 70-72 km and 77-78 km height regions. The use of wavelet transform in analyzing the data revealed previously unobserved 100m to 200m thin layers of turbulence within them.

Momentum spectrometry of fragments produced during dissociative ionization of molecules revealed changes in bond angles in the case of CO_2 and in symmetry in the case of CCl4 for specific state of ionization in each case.

Fossil records of short-lived, now extinct nuclide ^{26}Al in meteoritic Ca-Al-rich inclusions and Chondrules, (that are considered to be products of high temperature solar nebular processes), led the Planetary and Geosciences Division to conclude that the lifetime of the active solar nebula during which these objects formed was < 2.5 Ma.

Feldspars are alkali rich alumino-silicates and are ubiquitous minerals in the Earth's crust. The usefulness of feldspar mineral for radiation dosimetry and chronology was investigated by using Electron Paramagnetic Resonance at room temperature. The results provided evidence of dose dependent g-value of the line $g = 2.54$ and a new possibility for radiation dosimetry and geochronology, using feldspars.

Nitrogen plays a key role in oceanic primary productivity. N-uptake and f-ratios (new production/total production) of the Indian and Southern Ocean were studied in an attempt to evaluate their role in the Global Carbon Cycle. Results obtained from this study suggests that although the primary productivity is relatively low but f-ratio is high compared to other oceanic regions; thus making Southern Ocean as a potential region for high C-export to deep ocean.

The impact of a highly variable discharge of the river Brahmaputra on its water chemistry was assessed using Sr and $^{87}Sr/^{86}Sr$ isotopic composition. The results indicate that enhanced weathering observed during high discharge (monsoon period) is dominated primarily by carbonate weathering rather than silicate weathering.

Time-series analysis during winter time at an urban site (Hissar) in North India show distribution of organic carbon/ elemental carbon (OC/EC) ratio centering around 8.5±2.2. These values are significantly higher than 2, that is generally used as representative value for urban sites. These results suggest the need for a reassessment of primary and secondary OC in the Asian region based on existing emission models.

The Theoretical Physics Division made several important contributions during the year. A specific model that relates dark energy and dark matter to neutrino masses and provides a way to understand leptogenesis at the TeV scale within the model framework, was constructed. It was shown that B-mode polarization can be increased substantially by stimulated emission of gravitons by gravitational waves, in case the graviton background existed at the time of inflation. Studies of possible signatures of new physics in top quark decays suggest that the angular distributions of the leptons produced in top decay can provide information on anomalous top coupling that could be detected.

The study of synchronization in ecological systems was modeled based on coupled dynamical elements. This study led to understanding of the reason of extinction of species that happens under certain circumstances. Problems related to Ratchet effects in chaotic quantum systems are now becoming important in many biological systems and, for manipulating currents in semiconductor nano-devices, are also being pursued. Study of one plus two body embedded Gaussian orthogonal ensemble of random matrices with spin led to new exact results for embedded Gaussian unitary ensemble of two-body interactions for fermions with spin.

Exact solitary wave solutions of the one-dimensional Gross-Pitaevskii equation were obtained and the structure of the exact, dark and bright soliton solutions of the driven nonlinear Schrödinger equation was analyzed. Soliton solutions of strongly coupled Bose-Einstein condensates were obtained and their coherent control demonstrated. That a two-mode Fock state of bosons can develop into a quantum vortex and mimic entangling mechanisms such as beam splitter have been shown. In study of optical vortices, experimental as well as theoretical demonstration that the Wigner function can be used to determine whether the vortex is axial or non-axial have been provided. Also how it propogates in each case have been demonstrated.

The mechanical and electrical designs of the High Energy X-g ray (HEX) spectrometer to be deployed in the Chandrayaan-1 mission have been finalized. Fabrication has been planned in three stages, engineering, qualification and the flight model. Fabrication and testing of all the trays for the engineering model have been completed by interfacing the HEX detector package with processing electronics developed by SAID, ISRO Satellite Center. The integrated payload will soon be qualified through various tests and activities for realizing the flight payload have been initiated.

The results obtained from research conducted by PRL scientists during the year resulted in publication of a total of 134 papers with 103 in international high impact journals. Several PRL scientists are currently serving on the Editorial Boards of reputed national and international journals. PRL scientists participated in a large number of national and international conferences and symposia that resulted in publication of 31 contributions in conference proceedings. 99 invited talks/colloquia were presented by PRL scientists in various conferences/institutions.

PRL currently has 49 academic faculty, 50 technical faculty, 63 research scholars, 12 post-doctoral fellows, 6 project associates besides other short-term visitors. The faculty induction initiative has led to addtion of several new faculty members. Four Ph.D. theses were submitted during the year.

Several PRL scientists received **National and International awards and honours** during the year. These include fellowship and membership of Council of several Science Academies of India, Third World Academy Prize, Membership of International Scientific Steering Committees, President, Astronomical Society of India, and Instrumentation award from Indian Physics Association.

Looking ahead, the **11th Five Year Plan document** for the Laboratory was submitted to the Department of Space (DOS) for inclusion in the overall plan document of DOS. Major outlays for strengthening existing research activities and for new futuristic initiatives such as space based observations in Earth System Science, Planetary Exploration and Astronomy, have

been proposed. These will lay a strong foundation for future Planetary Science and Exploration programmes of the country by creating technological capabilities and the requisite human resources.

The **Fifth UN PG Course in Space and Atmospheric Sciences of CSSTEAP** was conducted by PRL during August, 2006-April, 2007. Ten participants from Asia Pacific countries and three from India took the course. The classes were conducted in the UN school premises in the Bopal campus of Space Applications Centre. Subjects in this course included Atmospheric Science, Ionospheric Physics, Solar Physics and Magnetospheres, Astronomy and Astrophysics and, Space Technology. The faculty included experts from PRL, Universities, Research Institutions, various ISRO centers and from US, Canada and Japan.

A four day **International Conference on Quantum Optics** was held in PRL during July 24-27, 2006. Several topics of current interest such as entanglement, quantum imaging, phase space distributions, quantum communication, quantum-classical correspondence were covered. Eminent Indian, American, British, Japanese, Australian and Italian scientists participated in the conference that was attended by nearly hundred participants.

Another **International conference on "Challenges for Solar Cycle-24"** was organized during 22-25 January 2007 as a part of scientific activities planned for the Jubilee year. The conference was attended by over 140 participants including forty international delegates. The keynote address on "Highlights and Problems in Solar Physics" by Prof. Markus J. Aschwanden set the tone of the meeting. Following the conference, a special session on **INDO-US collaboration in Solar Physics** was organized at Udaipur Solar Observatory, on 26 January, 2007, to discuss potential areas of Indo-US collaborative research in solar physics.

A **Winter School on Modeling of Planetary Atmospheres** was organized at PRL during 18 December 2006 - 6 January 2007. It was attended by 35 students from Indian universities and research Institutions. The courses included Structure and Dynamics of Planetary Atmospheres, Chemical, Radiation and Transport processes, Solar Wind Interaction with Planetary Atmospheres and Numerical Analysis and Mathematical Techniques. The Faculty for the course comprised scientists from PRL and other research centers.

A discussion meeting on **Imaging Payloads on Chandrayaan-1** was held in PRL on September, 4, 2006. The participants included Dr. U. Mall from the Max-Planck Institute, Lindau, Germany (Principal investigator of SIR-2), Dr. Carle Pieters from Brown University, USA (Principal Investigator of Moon Mineralogy Mapper), and scientists from PRL, Space Applications Centre and other ISRO centers.

The Seventh PLANEX workshop on **Planets, Satellites, Asteroids and Comets** was organized in PRL, Ahmedabad, during January 8-11, 2007. This was attended by thirty participants from universities and educational institutions. Two participants from the workshop were selected for further training at PRL in Planetary Science and Exploration.

The PLANEX group organized a meeting during January 14-15, 2007 for discussing data analysis approach for **Mini-SAR Experiment on Chandrayaan-1**. Seven Indian scientists and Dr. Keith Raney, representing the Mini-SAR team from Johns Hopkins University, USA, participated in the meeting.

A workshop on **"Neutrinoless Double Beta Decay"** was organized at PRL on 5th February, 2007 to review the status of the proposed Indian Neutrino Observatory and discuss different aspects of neutrinoless double beta decay experiment. Presentations were made by scientists representing various Institutes such as TIFR, BARC, PRL, SINP, IIT, Kharagpur and university of Lucknow, also Scientists from Europe presented their works.

ISRO's **Respond programme** for Space Sciences provides opportunity to scientists at Universities and academic institutions to conduct research projects. This is being administered by PRL since its inception in late 1970's. Over the last decade, RESPOND programme has grown both in the numbers of projects being sanctioned as well as in its overall budget. At present over 50 projects are at various stages of implementation. The annual **RESPOND Review meeting** was held in PRL during, 23-24 March, 2007 that reviewed progress of 26 projects funded under this programme.

The PLANEX programme is currently supporting over a dozen research groups at various places in the country to enable

them to carry out research in planetary sciences and allied fields. The annual **PLANEX review meeting** took place during March 26-27, 2007, that reviewed progress of 15 projects funded under this programme.

PRL continued its summer training programme for students from several universities for experimental and theoretical projects. 23 students and 3 Teachers that included students under the Indian National Science Academies initiative were hosted. In addition PRL hosted 3 University faculty members to spend extended time for collaborative research as PRL Associates.

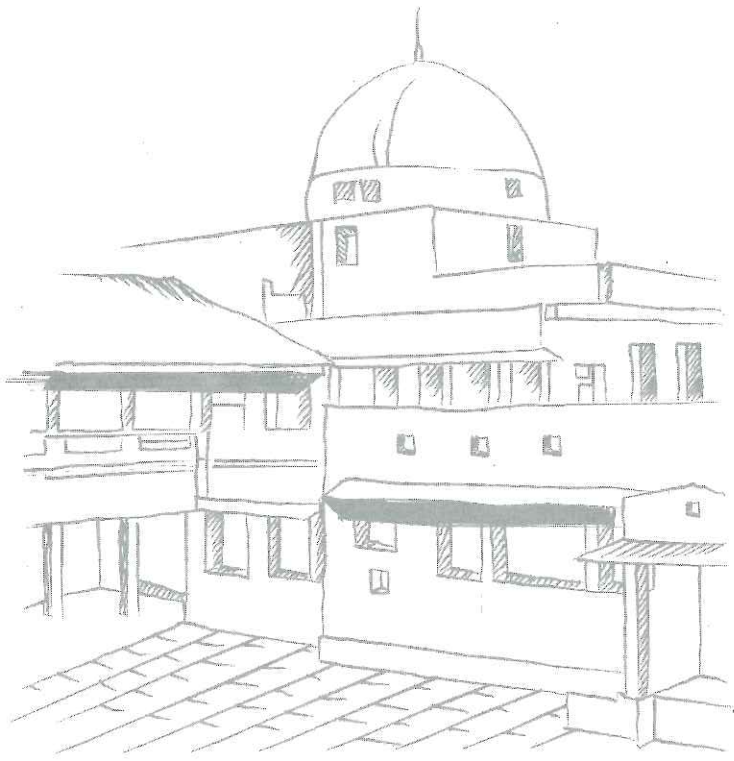
As a part of implementation and progressive use of Hindi in PRL, the Hindi Pakhwada was celebrated at PRL from September 14 - 28, 2006. The highlights of the celebrations included word quiz, essay, elocution, *Hamara Karya*, self written poetry competitions. A Technical Seminar in Hindi on Scientific Advancements in PRL during the last 60 years was held at PRL on 14 Sept., 2006. Bilingual publication of PRL News in Hindi and English started from July 2006. Two members from PRL participated in the Space Glossary Meeting held during 31st August to 4th September, 2006 at IIRS, Deharadun.

Science Day celebrations were held on February 24, 2007 in association with the Indian Physics Association, Ahmedabad Chapter. A student each from over 350 schools, accompanied by their teachers participated in the event that comprised multiple-choice written test for students and an interview. These led to the selection of five students for scholarships offered by PRL from the Aruna lal Endowment Fund, established by Prof. D. Lal, Honorary Fellow and former Director, PRL. Several other incentives and awards were also given. In parallel, a Science Quiz for the accompanying teachers with an emphasis on the theme 'More Crop per Drop', and an oral quiz with visual aids for the students were conducted.

The past year by was eventful for all of us at PRL in many ways. It was a time for celebration, reflection, introspection and for planning for the coming decades. I look forward to the future with deep anticipations. I expect it to be an era of new vigour and new science. The proposed strengthening of faculty should further accelerate the pace of scientific activities at PRL.

It is a pleasure and a priviledge to acknowledge and record the dedicated contribution of all the members of PRL, that resulted in a fruitful year for the laboratory. We thank the Council of Management of PRL for their wise counsel and unstinted support for an overall growth of PRL and its Science.

J.N.Goswami
Director



1947

PRL : AN OVERVIEW

Scientific Achievements

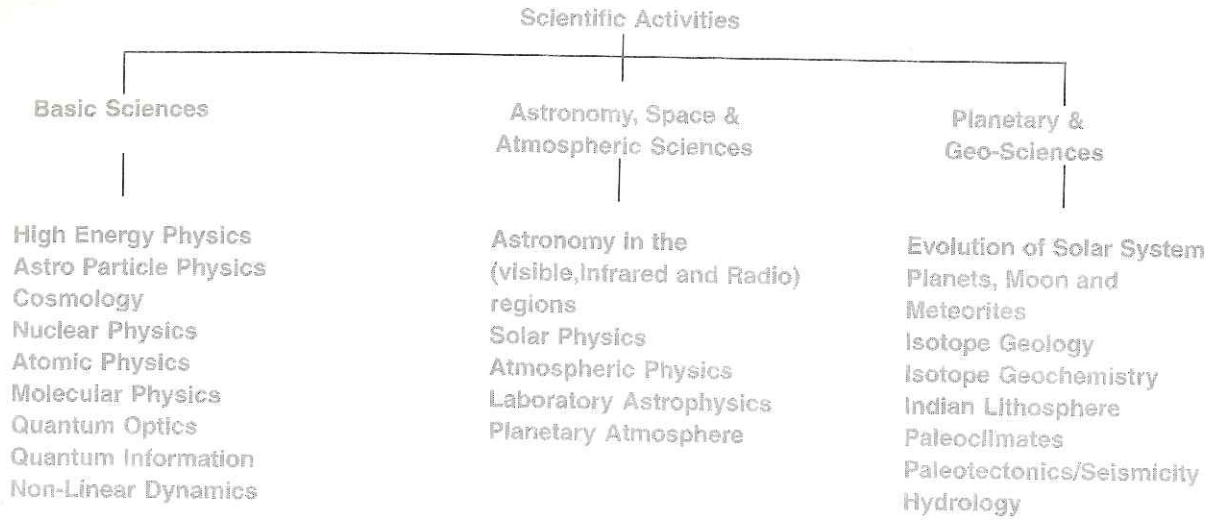
The research activities at PRL cover a large variety of themes with major research programmes in theoretical, experimental and applied physics. Some of the important contribution are highlighted below.

Astronomy and Astrophysics

The activities of the Astronomy and Astrophysics Division relate to studies of star formation, stellar evolution with emphasis on AGB stars and eruptive variables. Studies on our own galaxy and energetic stellar phenomena such as active galactic nuclei in distant galaxies are also conducted.

The well known recurrent nova RS Oph exhibited its sixth ourburst on 12 Feb 2006. This binary system consists of a red giant star with substantial stellar wind and a companion white dwarf. The system thus offers a unique opportunity to study the interaction of nova ejecta with circumstellar material. An intensive observing campaign of this object was launched from Mt. Abu observatory and spectroscopic data were obtained on a daily basis. These observations led to the detection of a near-infrared shock wave resulting from interaction of the nova ejecta with the red giant stellar wind. The observed temporal evolution of the shockwave is broadly consistent with the predictions of analytical models. Our observations also suggest that the white dwarf in the system has a relatively high mass of ~1.35 solar mass and is a potential candidate for a future supernova.

Asymptotic Giant Branch (AGB) stars represent later stages in the life of intermediate mass (sun-like) stars, following the exhaustion of core helium. Heavy mass loss from AGB obscures them in the visible region and near-infra-red spectroscopy is a useful tool to probe and understand the physical mechanisms and the nature of the AGB mass loss phenomenon. Using NICMOS camera and spectrograph at the Mt.Abu Observatory, near-infra-red spectra in the H (1.4 micron) and K (2.4 micron) bands have been obtained for 80 AGB and Post-AGB (PAGB) stars. Our results show that the equivalent widths of the CO (3-0) second overtone bands are better correlated with infra-red colours rather than the first overtone bands, mainly due to the differences in their excitation temperatures. Variability in the first overtone bands seen in a few PAGB stars indicates ongoing episodic mass loss in these objects.



A study of two solar wind "disappearance events" that occurred in March and May 2003 was carried out. These events had their origins in active region open fields that were located at central meridian. Since active regions on the Sun are often ignored as a source for the interplanetary magnetic field at 1 AU. This work highlighted the role of stable and unipolar outflows from the Sun that are responsible for such unusually long lasting density depletions in solar wind at 1 AU.

Solar Physics

High resolution X-ray spectra of solar flares in the energy range 4-20 keV observed by the SOXS Low Energy Detector Payload on board GSAT-3 suggested that multi-thermal power laws and non-thermal components are needed to explain the observed features rather than previously considered isothermal approach. The sub-keV energy resolution allowed the study of Fe-line and Fe/Ni line features in greater detail using multi-thermal diagnostics. The variation of equivalent width and peak energy as a function of temperature requires that the abundance ratio of Fe to Fe/Ni-line features reduces exponentially as a function of electron temperature.

H-alpha flare ribbons are the sites of impact of electron beam on chromospheric material. The resulting chromospheric evaporation is manifested as brightening in H-alpha wavelength. Signatures of such Flare ribbons were seen at enhanced levels in the "super active region" NOAA AR 10486, that appeared in the October 2003. An interesting photospheric phenomenon, viz. "Doppler ribbons" or localized velocity enhancements, was seen to accompany the H-alpha ribbons during the X17 flare of October 28, 2003. The observed Doppler ribbon could be a manifestation of a pressure impulse striking the photosphere, following explosive evaporation in the chromosphere.

High spatial-, temporal- and spectral-resolution filtergrams were used to study the dynamics of small scale phenomena on the sun. The intensity and velocity oscillations have been detected in small scale flux concentrations which indicate mode conversion of solar p-modes in magnetic fields.

A previously developed logistic-regression model for predicting space weather was refined using observations of geo-effective CMEs during 1996-2006. The new model demonstrated improved prediction (71%) for the super-intense events i.e. those CMEs which resulted in Dst index < - 200 nT. However, prediction of major geomagnetic storms is not as successful, and implies the need for identification of crucial solar parameters that control the geoefficetiveness of CMEs.

The phase II of Solar Vector Magnetograph (SVM) project including fabrication of new opto-mechcanical mounts and installation of a fully computerized robotic telescope mount at the island site has been completed. The instrument became operational in 2006 and formally commissioned on 20 February, 2007 at the Udaipur Solar Observatory. This instrument has already produced new science by establishing that the power of acoustic oscillations varies with the angle of inclination of the magnetic field vector. The Adaptive Optics

System (AOS), developed in house, is also nearing completion.

Space and Atmospheric Sciences

The research activities of the Division deal with the physical and chemical characterization. and the modeling of Planetary Atmospheres. Major programmes on atmospheric trace gases, aerosols, ionospheric and stratospheric processes etc. are pursued and plans for space-based studies of atmospheric processes are underway.

As a part of the Integrated Campaign for Aerosol, trace gases and Radiation Budget (ICARB), measurements of aerosols and trace gases over Bay of Bengal (BoB) and the Arabian Sea (AS) using ship-based, aircraft-borne and ground-based instruments were made during March 18 to May 11, 2006. A strong effect of convection was observed on the vertical distribution of ozone in the troposphere over the central BoB. On the other hand, significantly high aerosol optical depth was observed due to transport from the surrounding, densely, populated and industrialized eastern and central Indian regions.

Variation in the intensity of sodium airglow measured from Mt. Abu during November, 2006 revealed an increase in background sodium airglow intensity by a factor of nearly two after ~2-3 days of the peak of the Leonid shower. The cause for this delay in the response of sodium airglow intensity to meteor shower activity remains unresolved as it cannot be accounted for by known mechanisms such as the Chapman and Bates reactions.

Mesospheric turbulence was studied through simultaneous rocket-borne in-situ measurements of electron density at SHAR and MST radar at Gadanki. Two campaigns, the first during July, 2004 and the second in April, 2005, were conducted. A rocket-borne Langmuir probe flown on 8th April, 2005 from Thumba showed presence of strong turbulence in 70 -72 km and 77-78 km height regions. In addition to the main turbulent layers, previously unobserved 100 m to 200 m thin layers of turbulence have been delineated. The use of wavelet transform in analyzing the data revealed the presence of these thin layers.

Studies of momentum spectrometry of fragments produced during dissociative ionization of CO_2 show that the structure of CO_2 changed from linear to bent geometry when it was doubly ionized and dissociated. Similarly, symmetric molecules like CCl_4 change shape from tetrahedral to quasiplanar when it loses two electrons under an electron impact.

Planetary and Geosciences

Understanding the temporal evolution of planetary bodies in general, and the planet Earth in particular, is the focus of the Planetary and Geosciences Division. The studies cover various aspects of the early evolution of the solar system and the processes operating in and interactions between the different terrestrial reservoirs: the mantle, the lithosphere, the hydrosphere and the biosphere.

The duration of formation of the two early solar system objects, the Ca-Al-rich refractory inclusions (CAIs) and the chondrules, that are considered to be products of high temperature nebular processes, effectively defines the lifetime of the active solar nebula. Records of short-lived (now extinct) nuclide ^{26}Al, in these objects was used to infer this duration. While the duration of CAI formation is established to be a few times 10^5 years, so far the inferred duration of chondrule formation varied from less than a million years to three million years. Our study of chondrules from nine unequilibrated chondrites show that chondrule formation started ~1Ma after CAI formation and lasted <1.5 Ma. The longer duration of formation, inferred in earlier studies, appears to be an artifact of thermal metamorphism affecting some of the analyzed chondrules. Thus, the lifetime of the active solar nebula is now constrained to < 2.5 Ma.

A comprehensive investigation of nitrogen in individual chondrules of the three main chondrite classes has been undertaken to understand the nature of chondrules precursors and the chondrule formation environment. Our data suggest that chondrules from Ordinary and Carbonaceous chondrites had precursors that are different than their respective host chondrites, while those from Enstatite chondrites have similar precursors. Further, an additional component, over and above the earlier proposed components, is needed to explain the nitrogen isotope data in chondrules. Our data for nitrogen and argon isotopes suggest that insoluble organic matter could be the potential third component.

Internal distribution of heavy oxygen isotopes in ozone produced in stratosphere and laboratory shows an anomalous enrichment in heavy oxygen isotopes relative to oxygen from which it is formed. A new approach based on oxidation reaction of ozone with silver metal has been used to further study this phenomenon. The results show that $r^{49}(^{16,16,17}O/^{16,17,16}O)$ increases with total enrichment in ozone just as in the case of r^{50} ($^{16,16,18}O/^{16,18,16}O$). Further, asymmetric ^{17}O species are more enriched compared to symmetric ^{17}O species and this difference in enrichment decreases with increase in total ozone enrichment. These results will help in modeling mass independent enrichment of several atmospheric trace gases caused by transfer of isotopes from ozone.

Time series analysis over a span of 30-days during winter time at an urban site (Hissar: 29.2° N, 75.7° E; 210 m asl) in North India show distribution of organic carbon/elemental carbon (OC/EC) ratio centering around 8.5±2.2, whereas water soluble organic components (WSOC) have a wider range spanning from 6.7 to 42.0 $\mu g.m^{-3}$. Both WSOC and OC exhibit significant positive correlation with water-soluble K^+, suggesting their dominant contribution from biomass burning. The observed OC/EC ratios are much greater than 2, a value that is generally considered to be representative for urban sites while assessing primary and secondary OC in the Asian region using existing emission models. Revision of such assessment is therefore required.

Feldspars are alkali rich alumino-silicates and are ubiquitous minerals in the Earth's crust. An understanding of the physical properties of unpaired electrons in the feldspar matrix is needed to obtain insight into luminescence process and mechanisms of its thermal decay and hence usefulness of feldspar mineral for radiation dosimetry and chronology. Our study of several feldspar samples using Electron Paramagnetic Resonance at room temperature, provided a rare evidence of a dose dependent Line position at ~ g =2.54. This holds potential for new possibilities for radiation dosimetry and geochronology.

Extensive geochemical and isotopic investigations of the only known "dolomite carbonatite" complex in India in Rajasthan we carried out. Initial Sr isotope ratios in the analyzed samples suggested that these carbonatites are mantle-derived and a large-ion-lithophile element depleted mantle was the source of these magmas. Stable C and O isotope composition of the samples also support their magmatic origin.

Nitrogen plays a key role in oceanic productivity and hence its unavailability can be a limiting factor. Uptake of nitrogen and f-ratios (new production/total production) were investigated in the Indian Ocean in an attempt to evaluate its role in the Global Carbon Cycle. Data were taken from two cruises in eastern Arabian Sea and one cruise each in the equatorial Indian ocean and the southern ocean. Our results for Arabian Sea suggest enhanced downward transport of newly formed organic matter implying increased sequestration of carbon in the deep. Even though the productivity over a large area in the southern ocean is low, the f-ratio is moderately high signifying that a large part of production gets transported to deeper ocean. Thus the southern ocean has the potential to play a significant role in atmospheric carbon sequestration.

Almost 80% of water-discharge of Himalayan Rivers is controlled by south-west monsoon. A study was carried out to assess the impact of the discharge of highly variable river water chemistry of the Brahmaputra by analyzing bi-weekly samples collected over a period of about a year at Guwahati for Sr content and its isotopic composition. The results indicate enhanced weathering during monsoon attributable to cumulative effect of increase in drainage area and in physical weathering during monsoon. The results also suggest relatively lower contribution from silicate weathering during monsoon with concomitant increase in contribution from carbonate weathering.

Theoretical Physics

The Theoretical Physics Division is working in several broad areas that include High Energy Physics, Non-linear Dynamics and Quantum Optics and Quantum Information.

The high energy physics group continued its research in the areas of neutrino physics, collider-physics and in astro-particle physics that led to several important findings. The present day cosmological observations point to the existence of dark matter and dark energy. Understanding their origin and relating it to the known physics is a challenging task. Specific model which relates dark energy and dark matter to neutrino masses and

provides a way within the model to understand leptogenesis at the TeV scale, was developed.

The relation of the B-mode polarization in the cosmological microwave background (CMB) to the existence of the gravitational waves has been investigated. It was observed that this polarization can be substantially increased by the stimulated emission of gravitons by the gravitational waves, if the graviton background existed at the time of inflation. The predicted amount of polarization can be detected in future space based experiments such as the Planck Experiment.

The Large hadron-collider at CERN, that will soon be operational, is expected to pin down the properties of known particles. Studies of possible signatures of new physics in top quark decays led to the observation that the angular distributions of the leptons produced in top decay contain significant information on anomalous top couplings and can provide an easy way to detect such couplings.

Currently available experimental information in neutrino physics is used to test various theoretical ideas. Specific scheme based on grand unification was proposed which implies symmetric leptonic mixing matrix that is significantly different from the existing data.

Studies in nonlinear dynamics are focused on classical and quantum chaos, synchronization and complex networks, statistical aspects of nuclear spectra and random matrix theory. The study of synchronization in ecological systems, modeled based on coupled dynamical elements, has led to significant advances in our understanding of why extinction of species happens under certain circumstances. We are also pursuing problems related to ratchet effects in chaotic quantum systems that are becoming important in many biological systems and for manipulating currents in semiconductor nano-devices.

Random matrix theory is a useful tool for quantum chaos and statistical nuclear physics. In this context, we examined one plus two body embedded Gaussian orthogonal ensemble of random matrices with spin and additionally obtained new exact results for embedded Gaussian unitary ensemble of two-body interactions for fermions with spin. These results would help in a better understanding of spectroscopy of many particle nuclear systems with two-body interactions.

In the area of Quantum Optics and Quantum Information, the activities were focused on the dynamics of solitons and the study of classical and quantum vortices. Exact solitary wave solutions of the one-dimensional Gross-Pitaevskii equation, with time-varying scattering length and gain or loss, in various confinement regimes have been obtained. The structure of the exact, dark and bright soliton solutions of the driven nonlinear Schrödinger equation is analyzed. Soliton solutions of strongly coupled Bose-Einstein condensates were obtained and their coherent control demonstrated.

In our ongoing study of optical vortices, the sign of the vortex charge was determined by matching the experimental trajectory of the vortex with the theoretical trajectory for negative and positive charges. Both experimentally and theoretically it was demonstrated that the Wigner function can be used to determine whether the vortex is axial or non-axial and how it propagates in each case.

It was demonstrated that a two-mode Fock state of bosons can develop into a quantum vortex under the action of a generic Hamiltonian that generates linear SU(2) transformations and mimics a host of entangling mechanisms such as a beam splitter. Remarkably, this analysis is equally valid for a variety of initial states that can be prepared from a two-mode Fock state via a unitary transformation. As an example, a quantum vortex as the initial state was considered and conditions for its revival and charge conjugation, were obtained.

Planetary Exploration Programme (PLANEX)

The academic activities of the Planetary Sciences and Exploration (PLANEX) programme during the year centered broadly around two themes: (i) design and development of the engineering model of the High Energy X-ray (HEX) payload for Chandrayaan-1 mission and, (ii) research activities related to the evolution of Moon and Mars. Additional activities to fulfill the mandate of PLANEX to establish a National Facility for studies of planetary material, and enhance research efforts in Planetary Sciences across the country, were continued.

The High Energy X-ray (HEX) spectrometer to be deployed in the Chandrayaan-1 mission is primarily designed to study the nature of volatile transport on the moon using radon as a tracer, estimated through measurement of the 46.5 keV line from

^{210}Pb, a decay product of ^{222}Rn. The mechanical and electrical designs of HEX payload have been finalized. Fabrication has been planned in three stages; engineering, qualification and the flight model. Fabrication and testing of all the trays for the engineering model have been completed by interfacing the HEX detector package with processing electronics developed by SAID, ISAC. The primary specifications of energy resolution (10% at 60 keV) and detection threshold ($\leq$30 keV) are adequately met. The integrated payload will soon be qualified through various tests. Activities for realizing flight payload have been initiated. Further, using five band UV-VIS data of Clementine mission, an analytical approach to derive average iron and titanium concentrations of the central peaks of lunar craters, taking into consideration topography and other photometric constraints, has been devised.

As a part of establishing a national facility of sophisticated instruments for physical, chemical and mineralogical characterization of planetary materials, three analytical instruments (Electron Probe Micro Analyser (EPMA), X-Ray Flourescence Spectrometer (XRF) and Inductively Coupled Plasma Mass Spectrtometer (ICP-MS) were successfully commissioned after performance checks with standards. These facilities are being used by planetary scientists at PRL and by scientists from other places funded through the PLANEX programme. About twenty research groups from various Universities, IITs and Research Institutes are currently supported under PLANEX.

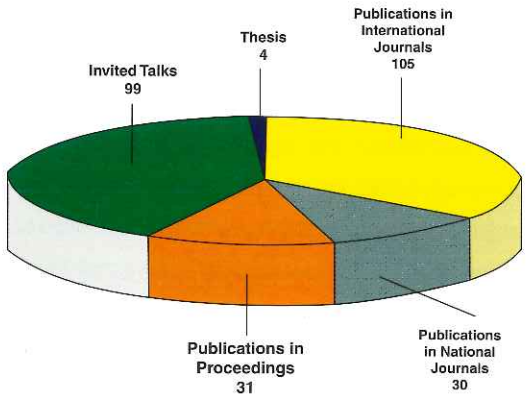


Fig 1 : Scientific Output of PRL

Scientific Publications and Participations

The research work carried out by PRL scientists are published in reputed national and international journals. PRL scientists are also invited to write review articles in books and journals in the fields of their specialisation. Research done at PRL is presented at national and international conferences and symposia. During the past year several PRL scientists were invited to present review/plenary/keynote papers in these meetings. Some of them served as chairmen and members of scientific committees for organising such conferences and symposia, and others are invited to convene and chair sessions during symposia and meetings. Fig : 1 provides a summary of the scientific contributions of PRL scientists during the last year.

Distinguished Visitors

PRL was priviledged to receive several noted scientists during the year. These scientists visited PRL for discussions and seminars/colloquia. Notable amongst these were the Honorable President Dr. A. P. J. Abdul Kalam, Shri Madhavan Nair, Secretary DOS and Chairman ISRO, distinguished Alumni of PRL and several close associates of PRL during its formative years. These included Professors J. E. Blamount, K. C. McKrekan, U. D. Desai, R. P. Kane and P. D. Bhavsar, among others.

Seminars and Colloquia

PRL maintained its tradition of weekly seminars and colloquia on a regular basis. Each division held specialized seminars by its own Scientific staff or by invited experts. A total of 150 seminars and 39 colloquia were held during the year. Several eminent scientists from within the country and abroad visited PRL during the year and gave Colloquium/ Seminars.

Conferences/Workshops/Courses/Symposia Organized

During the year, the following Conferences, Workshops, Courses and Symposia were organized:

1. International Conference on "Challenges for Solar Cycle-24" during 22-25 January 2007.

2. International Symposium on "Quantum Optics" during July 24-27,2006.

3. A workshop on "INDO-US collaboration in Solar Physics" on 26 January, 2007

4. The Fifth UN Postgraduate course in "Space and Atmospheric Sciences" during Aug 1, 2006 - April 30, 2007

5. A Winter School on "Modeling of Planetary Atmospheres" during December 18, 2006 - January 6, 2007.

6. Seventh PLANEX workshop on 'Planets, Satellites, Asteroids and Comets" during January 8-11, 2007.

7. A workshop on "Neutrinoless Double Beta Decay" on 5th February, 2007

Human Resource Development Initiatives

The laboratory serves as a major centre for human resource decvelopment in the country via its training programes at postgraduate levels. PRL imparts high quality training to its Ph.D students that includes a rigourous course work at the time of joining, experimental projects, seminars and colloquia. PRL also offers opportunties of post-doctoral research and helps students and post-doctoral fellows with particiation in national and international seminars and symposia. Currently PRL has 63 research fellows, 12 post doctoral fellows and 6 project associates, (Fig. 2).

PRL conducts a Associateship programme for faculty memebers of universities and colleges that enables them to carry out collaborative research with PRL faculty and with free

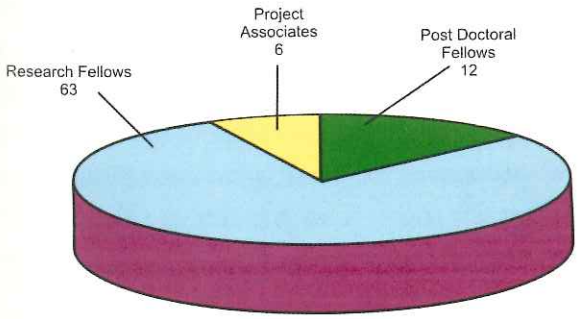


Fig 2 : Doctoral Post Doctoral and Other Programes

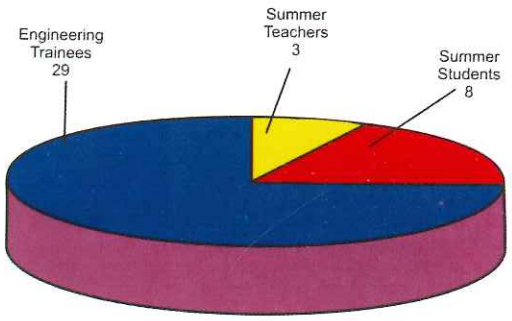


Fig 3 : Human Resource Development : Scientific

access to PRL facilites, both experimental and computational. In addition PRL welcomes students and teachers at all times of the year to visit its laboratories and learn about the work done here.

Training Oppurtunities

PRL organises extensive summer programmes for students and college teachers. The purpose is to initiate them to research methodologies by providing them with hands-on

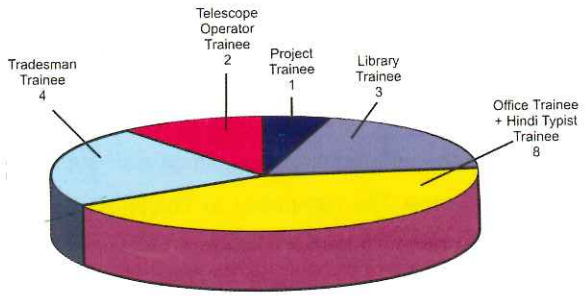


Fig 4 : Human Resource Development : Administrative & Allied Areas

exposure with experiments and computational aspects. Students in the final year B. Sc. degree first year M. Sc., and teachers from science colleges are considered for this programme. Selected students and teachers visit PRL for two months in summer, and work on specific experimental and theoretical research projects under the supervision of a faculty member. At the end of the programme, the students submit a report on the work carried out and present a seminar. PRL also provided project training in computer sciences and

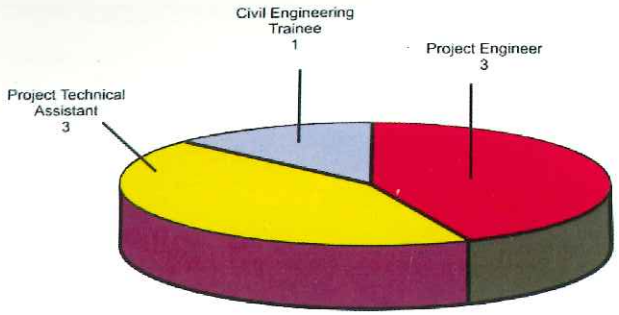


Fig 5 : Technical Programme in PRL

electronics and applications to postgraduate students. PRL offered training in electronics and computer engineering to students in final year engineering and diploma. Training programmes in library science, engineering and administrative services to a large number of students were also conducted.

This year, under the summer training programme PRL hosted 23 students and 3 Teachers for experimental and theoretical projects. These included students under the Indian National Science Academies initiatives. PRL hosted 3 university faculty members to spend extended time for collaborative research as PRL Associates. (Fig. 3,4,5).

Technical Facilities at PRL

PRL has state of art computational facilities based on IBM Power 5 machines, HP servers Dual Processor, which have terrabyte disk space. The campuses at Thaltej and Udaipur are connected with a high speed (100/1000 Mbps) links, which have been upgraded recently with a microwave, non-line of sight link to Thaltej campus. PRL's plans for national GRID computing facilities are nearing its final stage. The library and

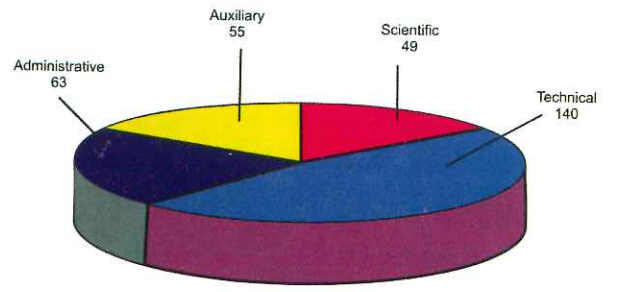


Fig 6 : Staff Structure of PRL

information facilities provide, on-line access, document delivery and interlibrary loan of scientific material and has subscription to over 148 Journals and has over 18000 books. The machine at PRL is a general purpose workshop and is capable of providing high-level machining frabication support for fabrications of payloads and experiments.

Administrative Support

The Scientific work at PRL was facilitated by an efficient administrative system, technical support and maintenance section. The administration comprises General Administration, Accounts Section, Estate Division, Purchase and Stores Division, the Maintenance Section and the Medical Cell. Computational Working in Administrative Areas (COWAA) was fully implemented and it is expected that soon, the accounts and information on all matters ranging from leave and payslips to budget and expenditure will be available online, (Fig. 7).

Initiatives in the use of Official Language

As a part of efforts towards implementation and progressive use of Hindi in PRL, the Hindi Pakhwada was celebrated at PRL from September 14 - 28, 2006. The highlights of the celebrations included word quiz, essay, elocution, Hamara Karya, self written poetry competitions. A technical seminar in Hindi on Scientific Advancements in PRL during the last 60 years was held on 14 Sept., 2006. Bilingual publication of PRL News started in July 2006. Space Glossary Meting was held during 31st Aug. to 4th Sept. 2006 at IIRS, Deharadun. Two members participated from PRL.

National Science Day Celebration

Science Day celebrations were held at PRL on 24 February, 2007. The highlight of the Science Day Programme for the last several years has been the selection of 5 students of Classes IX or X from all over Gujarat, for a scholarship endowed by the Aruna Lal Foundation. One student each, from over 350 schools registered for the event this year and 355 students, the largest number to date, participated. This was the highest response so far. Each student was accompanied by either a teacher or a parent.

The programme began with a multiple-choice written test for students. In parallel, a Science Quiz was conducted for the

accompanying teachers with an emphasis on the theme 'More Crop per Drop'. The written test responses were evaluated and the top 18 participants were short-listed for an interview. The interviews were conducted in the afternoon, and parallely, an oral quiz with visual aids was conducted for the next 18 students in the merit list. The programme ended with the distribution of prizes for the quiz and award of the scholarships. The scholarship winners were Suyash Roongta of Maharaja Agrasen Vidyala, Ahmedabad, Nachiketa Adhikari of Udgam School, Ahmedabad, Nihit Desai of S N Kansagara School, Rajkot, Aonkan Ghosh of Anadalaya, Anand, and Nirmalya Kundu of Delhi Public School, Ahmedabad.

Awards and Honours

Prof. U. R. Rao

1. Appointed Co-Chairman, Governing Council of National Center for Antarctic Research, Goa.
2. Appointed Chairman, Governing Council of Indian Institute of Tropical Meteorology, Pune.
3. Appointed Member, Central Board of Directors, Reserve Bank of India.
4. Appointed Additional Director, Bharatiya Reserve Bank Note Mudran Pvt. Ltd., Bangalore.
5. Awarded Life Time Achievement Award of Indian Space Research Organization, Bangalore.
6. Awarded the D.Sc. (Hon. Causa) from the Indian Institute of Technology, Delhi.
7. Awarded the Distinguished Scientist Gold Medal of the Karnataka Science & Technology Academy.

Prof. J. N. Goswami

1. President, Astronomical Society of India, 2007-2009
2. Council Member, Indian Academy of Science, Bangalore, 2007-09
3. Member, Governing Council, Indian Institute of Tropical Meteorology (IITM), Pune.
4. Member, Governing Council, Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune.

Prof. G.S. Agarwal

Awarded, Doctorate (Hon. Causa), by the University of Liege, Belgium.

Prof. S. Krishnaswami

Elected as one of the Directors and nominated to the Board of the Geochemical Society.

Prof. B.L.K. Somayajulu

National Award in Ocean Science and Technology – 2006 by the Ministry of Earth Sciences, New Delhi.

Prof. A.K. Singhvi

1. Elected, Fellow of the Luminescence Society of India
2. Awarded the Decennial Medal by the Indian Geophysical Union

Prof. R. Ramesh

1. Received the TWAS Prize for Earth Sciences, 2006.
2. Elected Fellow of the Geological Society of India in 2006.

Prof. A. S. Joshipura

Elected, Fellow of the Indian National Science Academy

Prof. U. Sarkar

Elected, Fellow of the Indian National Science Academy

Prof. S.V.S. Murty

Nominated as a member of Nomenclature Committee of the Meteoritical Society.

Dr. Bhas Bapat

S.N. Seshadri Instrumentation Award of the Indian Physics Association.

Dr. J. S. Ray

Awarded BOYCAST Fellowship of Department of Science and Technology (DST), New Delhi.

Prof. M. M. Sarin

Member, Research and Advisory Council, Indian Institute of Tropical Meteorology, Pune.

Dr. S. K. Singh

Nominated as a member of Scientific Steering Committee of GEOTRACES, an International programme of the Scientific Committee on Ocean Research (SCOR).

Prof. A. Jayaraman

Appointed as the Director, National Atomspheric Research Laboratory.

Dr. J. P. Das

Awarded best oral presentation by research scholars at the 12th ISMAS Workshop held at Goa, March 25-30, 2007

Diamond Jubilee

1947-2007

Diamond Jubilee Celebrations

On November 11, 2006, Physical Research Laboratory (PRL) crossed an important milestone and entered sixtiet year of its existence. The Diamond Jubilee celebrations were inaugurated by His Excellency, the President of India Dr. A. P. J. Abdul Kalam. The function was also graced by H.E. the Governor of Gujarat, Shri Nawal Kishore Sharma Hon'ble Chief Minister of Gujarat, Shri Narendra Modi and the Minister for Education, Govt. of Gujarat, Smt. Anandibe Patel. Dr. G. Madhavan Nair, Chairman ISRO and Secretary DOS, Prof. U R Rao, Chairman, Council of Management o PRL, Past directors of PRL, members of the PRL Council, senior members of other ISRO centres and eminen dignitaries of the State of Gujarat and Hari Om Ashram trust also graced this occasion.

Prof. J. E. Blamont from France and Prof. K. G. McCracken from Australia were specially invited on this occasion t honour them for their contributions to PRL during its formative years. Profs. R. P. Kane, U. D. Desai and P. D. Bhavsar the first research scholars of PRL, traveled from overseas to relive the PRL life of yester years during the Jubile celebrations. Mrs. Mrinalini Sarabhai and members of Sarabhai family also graced the occasion. Members of PR family, including past and present alumni, faculty and staff members participated enthusiastically.

The inaugural function began with invocation, lighting of lamps and a welcome address by Prof. J. N. Goswam Director, PRL. Dr. Madhavan Nair, in his address, outlined the vision of the Department of Space for the coming decad that would provide new opportunities for scientific experiments using space platforms. These will start with th launch of dedicated science missions, the "Chandrayaan-I" for remote saving study of the Moon and the "Astrosat mission for studies of celestial objects in the UV and X-ray windows. He noted that plans are being made for othe future space and planetary exploration missions where PRL is expected to play a substantive role. Prof. U.R. Rao gave an exuberant overview of growth of research activities of PRL over the last six decades and highlighted the research done during the last decade in the areas of Astronomy, Solar Physics, Atmospheric Sciences, Planetary and Geosciences and Theoretical Physics. He also dwelled on the future challenges before PRL to retain its unique place in the national and international context. Shri Narendra Modi, Hon'ble Chief Minister of Gujarat, in his address paid glowing tribute to Dr. Vikram Sarabhai and his vision. He outlined his plans for all round development of the State o Gujarat and his expectations from the scientific community and particularly from PRL. Shri Nawal Kishore Sharma H.E. the Governor of Gujarat, outlined the societal needs and emphasized the key role the scientific community could play in shaping the destiny of the country.


PHYSICAL RESEARCH LABORATORY
Diamond Jubilee Celebrations
R.TOLAT

The inspiring address by the President began with, *"When I am with PRL for celebration of Diamond Jubilee – that is 60 years of useful scientific, technological missions, I realize the PRL has orbited around the sun 60 times, and at the same time, it has seen growth of many scientists and technologists with scientific achievements."* The President recounted his close association with PRL scientists and their collaborators from USA, France, Germany and USSR during the sixties as a project engineer to ensure their payloads worked in a rocket environment and provided useful data. He outlined the challenging research problems being pursued by PRL in the areas of Astronomy, Space and Atmospheric Sciences, and Planetary- and Geo-Sciences and how these would provide important inputs to India's space science programme. He noted *"What is impressive is the combination of theoretical work, experimental work and mission mode work. I am glad to know the contribution of PRL in Chandrayaan-1 mission. As we look at the next twenty years, PRL is rightly setting its eyes on understanding the origin and evolution of solar system objects and missions to Moon, Mars and Asteroids."* He also suggested ways and means to overcome the major problem of attracting young scientists to the scientific establishments. He finally added *"PRL is indeed the cradle of space Science, Space Technology and Space Applications and above all is creating leaders in Science and Technology. I would like to wish PRL and its members all the best."*

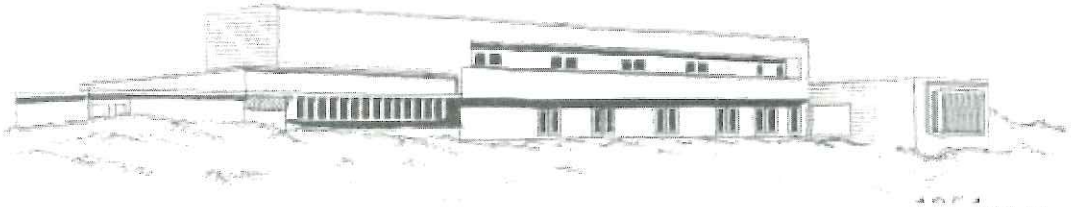
A highlight of President's visit was a special interactive session with PRL research scholars where he not only addressed them but also answered some of their questions. He exhorted the students to serve the nation to the best of their abilities, without prejudice and with commitment.

The curtain raiser to the Diamond Jubilee Inaugural function was a symposium on "Recent Excitements in Science and Future Perspectives" organized by the PRL Alumni Association on 10th November. The keynote address in the symposium was given by Prof. J. E. Blamont that was followed by talks on a wide range of topics given by alumni of PRL. Reminiscences by alumni and past faculty in the late afternoon, who recounted their early days at PRL and shared their excitements, their frustration, joys and fun of "those early days", made the event truly nostalgic and brought tears of joy to many. Prof. Blamont and Prof. K. McCracken reminisced visits to PRL and their long association with Prof. Sarabhai. Profs. U. R. Rao, P. D. Bhavsar, R. P. Kane and U. D. Desai, who started their research career with Prof. Sarabhai, recounted their early formative days at PRL and the family-like environment that pervaded PRL .

Four international conferences, several symposia, open house and public lectures are planned as part of PRL's Diamond Jubilee year. A few of these events have already taken place during the period of this report.

The open house of PRL, organized during November 11-14, 2006, was aimed to showcase the work being done by PRL. Interactive experiments and illustrative displays were created for the purpose and enabled communication of Science in PRL to the public. Over 50 display boards were made and 15 experiments were designed to enable students to visualize the fascinating aspects of PRL science. Over 10,000 students and the members of the public visited the exhibition.

For all those associated with PRL in the past and present, the programmes marking the inauguration of the Diamond Jubilee of PRL will remain etched in their memory as an event in their lifetime.



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4. R.J. Barber, D.P.K. Banerjee, N.M. Ashok and J. Tennyson, "Use of the BT2 water line list to determine the rotational temperature and H2O column density of circumstellar envelope on five dates", Proceedings of the conference on 16-19 May, 2006 in Los Concajos, La Palma, Spain. L. Romano, M. Corradi and U. Munari (Eds.), The Nature of V838 Mon and its Light Echo, ASP Conference Series, 324, 2007., 95 - 102 (2007)

5. H. O. Vats, H. S. sawant and H. Chandra, "Solar wind RAM pressure and the geomagnetic activity", 36th COSPAR Scientific Assembly 16-23 July 2006, cosp. 36, 985 Elsevier Pub. Ltd., U. K., (2006)

6. R. Jain, N. J. Bhatt, and L. Bharti, "Solar X-ray Spectrometer (SOXS) Mission – Observations and New results", Proceedings of the ILWS Workshop, Goa, India on February 19-24, 2006 on "Solar Influence on the

Heliospeher and earth's Environment: Recent Progress and Prospects", N. Gopalswamy and A. Bhattacharyya (Eds.), ISBN 81-87099-40-2 p. 54-60 (2006)

7. L. Bharti, R. Jain, C. Joshi and S. N. A. Jaaffrey, "G-Band Bright Points and Photospheric Magnetic Fields", Solar Polarization 4, ASP Conference Series, 358, 61-64, Proceedings of the conference held on 19-23 September, 2005, in Boulder, Colorado, USA. Eds. R. Casini and B. W. Lites, (2006)

8. L. Bharti, R. Jain, C. Joshi and S.N.A. Jaaffrey, "MHD Waves Observed in Isolated Bright Points," Proceedings of the Conference on Solar MHD Theory and Observations: A High Spatial Resolution Perspective, 18-22 July, 2005, at the National Solar Observatory, Sacramento Peak, Sunspot, New Mexico, USA. Eds. J. Leibacher, R. F. Stein, and H. Uitenbroe., ASP Conference Series, 354,13-15, (2006)

Theoretical Physics

9. S. D. Rindani, "Physics prospects at a linear $e^+ e^-$ collider", at the IX Workshop on High Energy Physics Phenomenology (WHEPP9), Bhubaneswar, Jan. 2006, Pramana 67, 579-596 (2006)

10. V.K.B. Kota, "Mean-field Approach for Interacting Boson Models: New Applications", in Proc. of National workshop on Relativistic Mean Field Theory in Nuclear Physics, IOP, Bhubaneswar, 16-24 July, 2006, S.K. Patra and A. Ansari Eds., Allied Publishers, New Delhi, 237-254, (2006)

11. V.K.B. Kota, "Chaos, Two-body Ensembles and Inputs for Nuclear Astrophysics", N.D. Chavda and R. Sahu, in the Proceedings of the DAE-BRNS Symposium on Nuclear Physics, Maharaja Sayajirao University of Baroda, 11-15 Dec. 2006, Eds. S. Kailas, S. Kumar and S. Santra, Vol.51 p. 163-172(2006)

12. S. Sree Ranjani, A.K. Kapoor and, P. K. Panigrahi "Designing bound states in a Band as a Model for a Quantum Networks", "Quantum Computing Back Action 2006", American Institute of Physics, Conference Proceedings, 864, 236 (2006).

13. P. K. Panigrahi, M. Gupta, A. Pathak and R. Srikanth, "Circuits for distributing Quantum Measurement", "Quantum Computing Back Action 2006", American Institute of Physics conference proceedings, 864, 197 (2006).

Space and Atmospheric Sciences

14. "Efficiency Enhancement of Optically Pumped FIR Laser", Ashish Dubey and Hemant Dave, International conference on Infrared and Millimeter waves, Terahertz, 394-395 (2006)

15. "Modified Oversize Cavity for THz Laser", Ashish Dubey and Hemant Dave, SPIE Int. Sym. on integrated optoelectronic devices, THz and GHz Electronics and Photonics V, Paper No. 6120-5, San Jose, USA, Jan. 21-26, (2006)

16. "Geometry of dissociating molecular ions", B. Bapat, Proceedings of XVI National Conference on Atomic and Molecular Physics, Allied Publishers, TIFR Delhi, Jan. (2007)

17. "Dissociative photo-multiple-ionisation of CO and CO2", B. Bapat, Proceedings of the 7th Asian International Symposium on Atomic Physics, New Journal of Physics : Conference Proceedings (2007)

Planetary Science and Exploration

18. M. Shanmugam, Y.B. Acharya and H. Patel. "CdZnTe : The new technology semi-conductor detector based nuclear instrument for medical and industrial applications", Proc. National Symposium on Instrumentation (NSI-31), Gwalior, 12-15 October (2006)

19. D. Dhingra "Radial mineralogical trends in fresh impact craters on Moon – formation processes and significance", Lunar and Planetary Science 38 (2007)

20. N. Srivastava. Geochemical estimation of iron and titanium for central peaks of lunar craters. Lunar and Planetary Science 38, (2007)

Planetary & Geosciences Division

21. R. Bhushan S.K. Singh, G.S. Burr and A.J.T. Jull "Paleo-climatic studies from sediments in the Bay of Bengal", Proc. 12th ISMAS Workshop, March 25-30, 2007, Goa (2007)

22. N. Chandrasekar and R. Ramesh, "Damages due to Tsunami in the south-western coast of India", in : The Indian Ocean Tsunami", eds. T. S. Murty, U. Aswathanarayana and N. Nirupama, 351-363, Taylor and Francis, London (2007)

23. J.P. Das and S.V.S. Murty, "Nature of precursors and formation environments of chondrules based on nitrogen and noble gases studies of individual chondrules", Proc. 12th ISMAS Symposium cum Workshop on Mass Spectrometry, RSP-2 (2007)

24. R. R. Mahajan and S. V. S. Murty, ``Sources & exess nitrogen in lunar soils : Clues from N and Argon in lunar Meteorite", Y 983885, Antarctic Meteorites XXX 50-51.

25. M. Tiwari and R. Ramesh, "Indian monsoon – Solar connection", Proceedings of the 12th ISMAS Workshop, Goa, India, March 25-30, 2007

26. R. Rengarajan, S.K. Singh, A.K. Sudheer and M.M. Sarin "Tracing the sources of mineral aerosols over Ahmedabad with 87Sr/86Sr", Proc. 12th ISMAS Workshop, March 25-30, 2007, Goa (2007)

27. S. Prakash, R. Ramesh and M. S. Sheshshayee, "High new productivity during a Noctiluca scintillans bloom in the northeastern Arabian Sea", Proceedings of the 12th ISMAS Workshop, Goa, India, RSP13, March 25-30, 2007

28. S. Prakash and R. Ramesh," Quantifying ocean productivity using 15N and continuous flow ass spectrometry", Proceedings of the 12th ISMAS Workshop, Goa, India, CP14, March 25-30, 2007

Library

29. N. Anilkumar 'Indian Consortia Models : FORSA libraries' Experience' in LISA V, International conference, Cambridge, June 2006.

30. N. Anilkumar 'Copyright Amendments in digital age : A comparative study', MANLIBNET Convention, Nirma University, Ahmedabad 18 – 20 September 2006

31. N. Anilkumar 'Transition of PRL library from Traditional to Digital library' – in a workshop on Libraries, ISRO, SAC, Ahmedabad 21-22 November 2006.

Publications For Education

1. D. Angom, "H. A. Bethe : Life and his works", People's Science Network, 4, 34-37 (2006)
2. P. K. Panigrahi, "Harmonic Oscillator: A Different Perspective", Physics Education 23, 135-138 (2007)
3. M. Vyas and P. K. Panigrahi, "Generic Solutions of Commonly Encountered Equations", Physics Education 23, 299-302 (2007)
4. A. Jayaraman, "Aerosols and their radiative forcing over South Asia", Global Change News Letter, 65, 16-17 (2006)

Thesis submitted

1. **Dilip Ganguly**

   Observational study of urban aerosols: Long range transport and estimation of their radiative forcing. (2006) Gujarat University.

2. **Y. C. Nagar**

   Methodological Aspects of radiation dosimetry of natural radiation environment using luminescence techniques: New minerals and applications. (2007) Gujarat University.

3. **J. P. Das**

   Laser probe mass spectrometric study of nitrogen and noble gases in individual chondrules from different classes of chondrites. (2007) Mohan Lal Sukhadia University, Udaipur.

4. **R. D. Deshpande**

   Groundwater in and around Cambay Basin, Gujarat: Some Geochemical and Isotopic Investigations. (2006) M.S. University of Baroda.

Technical Reports

1. Falgun Patel and Nupur Jain , Software Development for Data Processing and Analysis of Data from "SOLAR X-RAY SPECTROMETER (SOXS)" Mission Onboard GSAT-2 Spacecraft."

2. R. Jain, A. Ambastha, P. Janardhan, H.O. Vats, B.N. Dwivedi, W. Uddin, P.K. Manoharan and R. Kariappa, "Imaging Ultraviolet Spectro-Coronagraphs Mission" (IUSCM) : Proposal for Small Satellite Mission of ISRO.

Invited Talks

Astronomy and Astrophysics

B.G. Anandarao

1. "Multi-wavelength Studies of Gaseous Nebulae", at the International Workshop on UV and Multiwavelength Astronomy with ASTROSTAT', Indian Institute of Astrophysics, Bangalore, Sep. 27-29, 2006

2. "The Post-main sequence Evolution of Sun-like Stars", Colloquium given at the Astronomy and Physics Department, California State University at Northridge, Northridge, California, USA, 9 Nov., 2006

Hari Om Vats

3 "Solar radio astronomy", National Workshop on Recent Advances in Solar Physics Meerut College, Meerut, 8 November 2006

4. "Solar radio emission and coronal rotation", INCURSI 2007, NPL, New Delhi, 23 February, 2007

U. C. Joshi

5. "Polarimetric observations of cometary dust", Workshop on Dust in Astrophysics, Kavalur, 24-27 February 2007

Rajmal Jain

6. "Study of X-ray Emission Characteristics of Coronal Line Features Using Observations of SOXS Mission" at the 37th Meeting of the American Astrnomical Society (AAS), Solar Physics Division, held at University of New Hampshire, Durham, USA, during 25-30 June, 2006

7. "SOXS for IHY- 2007 and Beyond" at 2nd UN/NASA workshop on International Heliophysical Year and Space basic science" held at Indian Institute of Astrophysics, Bangalore, India during 27 November – 01 December 2006

8. "X-ray Emission from Solar Flares" at International

Conference on Challenges for Solar Cycle -24 held at Physical Research Laboratory, Ahmedabad during 22-25 January, 2007

S. Ganesh

9. "Automation of an Astronomical Instrument with GNU/ Linux and RTAI", in National Conference on Current Trends in Technology, Nirma University, Ahmedabad, 30 November to 2 December 2006

10. "Dust and Interstellar Extinction in the Inner Milky Way", Workshop on Dust in Astrophysics, Kavalur, 24 – 27 February 2007

Ashok N.M.

11. "Stellar outbursts, pulsations and extrasolar planets" at PRL Alumni Association Symposium on Recent Excitements in Science and Future Perspectives, at PRL, Ahmedabad, on November 10, 2006

12. "Study of Comets and Kuiper Belt Objects" at VIIth Planex Workshop on Planets, Satellites, Asteroids, Comets, at PRL, Ahmedabad, during January 8-10, 2007

13. "Mid-Infrared View of the Galactic Plane : Spitzer Results from GLIMPSE", at XXVth Meeting of the Astronomical Society of India, at Osmania University, Hyderabad, February 7-9, 2007.

14. "Astronomical Photometry" at Indo – French School in Astronomical Observations, at IUCAA, Pune, February 12-15, 2007

Solar Physics

Ashok Ambastha

15. "Magnetic and velocity field response of a large solar flare", TIFR Colloquium, Mumbai, June 6, 2006

16. "Signatures of large flares on photospheric magnetic and velocity fields", 2nd UN/NASA Workshop on the International Heliophysical year and Basic Space Science, at IIA, Bangalore, November 27- December 1, 2006

17. "Solar activity", International Winter School on Solar Physics, Kodaikanal, December 11-22, 2006

18. "Helioseismic effects of energetic transients", International Conference on Challenges of Cycle 24, held at PRL, Ahmedabad, January 22-25, 2007

19. "Excitation of solar p-modes by energetic transients", 25th Meeting of Astronomical Society of India, Osmania University, Hyderabad, February 7-9, 2007

P. Venkatakrishnan

20. "Solar magnetism: Measurement techniques", National Workshop on Solar Physics, Meerut University, Meerut, November 7-9, 2006

21. "Solar magnetism: fundamentals", 2nd UN/NASA Workshop on the International Heliophysical year and Basic Space Science, at IIA, Bangalore, November 27-December 1, 2006

22. "Multi application solar telescope and solar cycle 24", International Conference on Challenges for Solar Cycle 24, PRL, Ahmedabad, January 22-25, 2007

23. "Rapporteur talk on solar and solar system physics posters", 25th Meeting of Astronomical Society of India, Osmania University, Hyderabad, February 7-9, 2007

24. "Observatory reports: Udaipur Solar Observatory", 25th Meeting of Astronomical Society of India, Osmania University, Hyderabad, February 7-9, 2007

Nandita Srivastava

25. "How good is the prediction of the space weather based on solar and interplanetary parameters?", WPGM workshop, Beijing, July 24-27, 2006

26. "Coronal mass ejections" at the National Workshop on Solar Physics, Meerut University, Meerut, November 7-9, 2006

27. "On the study of kinematics of eruptive quiescent prominences observed in He 304 Å ", International Heliophysical Year Meeting, Bangalore, November 27-December 1, 2006

28. "Space weather prediction models: Success, Limitations and Challenges", International Conference on Challenges for Solar Cycle 24, workshop at PRL, Ahmedabad, Jan 22-26, 2007

Shibu. K. Mathew

29. "Properties of sunspots in cycle 23: Dependence of brightness on sunspot size and cycle phase", International Conference on Challenges for Solar Cycle 24, workshop at PRL, Ahmedabad, Jan 22-26, 2007

Theoretical Physics

S. Mohanty

30. "Thermal effects on inflation power spectrum", International Conference on Renormalization Group in Gravity and Cosmology, Barcelona, July 11-15, 2006

R. Rangarajan

31. "WMAPping the Inflationary Universe", at the 17th DAE-BRNS High Energy Physics Symposium at the Indian Institute of Technology, Kharagpur, December 11-15, 2006

H. Mishra

32. Superconductivity : from Quark matter to ultra cold atoms, Colloquium given at Institute of Physics Bhubaneswar, 26 June 2006

R. E. Amritkar

33. "Spatial synchronization and extinction of species", Dynamic Days Asia Pacific 4 (DDAP4), Pohang, Korea July 12-14, 2006

34. "Spatially synchronous extinction of species under external forcing", 8th Taiwan International Symposium on Statistical Physics (StatPhys-Taiwan-2006), Academia Sinica, Taipei, Taiwan, June 21-26, 2006

35. "Synchronization and Control of nonlinear dynamical systems", 8 lectures at the SERC school on Nonlinear Dynamics, Indian Association for the Cultivation of Science, Kolkata, 14-16 Dec, 2006

D. Angom

36. "Pairing in two component ultracold fermionic atoms", 7th Asian International Seminar on Atomic and Molecular Physics, IIT, Chennai, 4-7 Dec, 2007

37. "Coupled-cluster method and time reversal violations in atoms", Invited talk, Recent Trends in Many Body Methods for Electronic Structure and Properties of Atoms and Molecules, Bhubaneswar, 11-13 Jan, 2007

38. "Atoms in isolation and company", Trends in Computational Materials Science, JNCSAR, Jakkur, 15-17 Feb, 2007

39. "BEC in dilute atoms", Regional meeting of IAPT, SP University, Anand, April 11, 2007

V.K.B. Kota

40. "Two-body Ensembles with Group Symmetries for Chaos and Regular Structures", in the International Conference on Frontiers of Nuclear Structure, held in Shanghai (organized by Shanghai Jiao Tong University, China) during June 12-17, 2006

41. "Embedded Random Matrix Ensembles for Many-body Chaos", in the International Summer School on Chaos in Classical and Quantum Systems, held at El Escorial, Madrid (under the auspices of the Foundation of Universidad Complutense, Madrid), during July 17-21, 2006

42. "Chaos, Two-body Ensembles and Inputs for Nuclear Astrophysics", in the DAE-BRNS Symposium on 'Nuclear Physics' held at the Maharaja Sayajirao University of Baroda (India) during December 11-15, 2006

43. "Nuclear Models for Double Beta Decay: An Overview", in the Workshop on "Neutrinoless Double Beta Decay', held at Physical Research Laboratory, Ahmedabad (India) on February 5, 2007

P. K. Panigrahi

44. "Solitons in Bose-Einstein Condensate"in the 2nd International Conference on Current Developments in Atomic, Molecular and Optical Physics with Applications, March 21-23, 2006, Delhi University, Delhi.

45. "Manipulating solitons in optical fiber through distributed parameters" in Photonics-2006, University of Hyderabad, Hyderabad, Dec. 13-16, 2006.

46. "Solitons in BEC and their coherent control" in XVI

National Conference on Atomic and Molecular Physics, TIFR, Mumbai, Jan. 8-11, 2007.

47. "Periodicities in financial time series: A wavelet perspective", in International conference on Econo-Physics, Saha Institute of Nuclear Physics, Kolkata, March 11-15, 2007.

48. "Sub-Planck structure of entangled Cat-states", in Conference on Quantum Optics & Quantum Information, Controlling Soliton dynamics in optical fibers, JNU, Delhi, March 16-18, 2007.

J. Banerji

49. "Signatures of Fractional Revivals and Sub-Planck Scale Structures in the Kirkwood-Rihaczek Representation", International Symposium on Quantum Optics-2006, 24-27 July, 2006, PRL, Ahmedabad

50. "Novel resonators and interferometers using self-imaging waveguides", Indo-UK workshop on Recent Advances in Fiber Optics and Photonics, IIT Roorkee, 22-25 August, 2006

51. "Novel resonators and interferometers based on self-imaging waveguides", XXXII Optical Society of India (OSI) Symposium on Contemporary Optics and Applications, Controlling Soliton dynamics in optical fibers, M. S. University, Vadodara, 1-3 March, 2007

R. P. Singh

52. Optical vortices and their coherence properties, International Conference on Lasers and Nanomaterials (ICLAN), University of Calcutta, Kolkata, Nov. 30 – Dec. 2, 2006

53. "Optical vortices and logic gates", XXXII Optical Society of India Symposium on Contemporary Optics and Applications, M.S. University, Baroda, March 1-3, 2007

Utpal Sarkar

54. "Leptogenesis, Dark Matter, Dark Energy, and the Neutrinos", at Joint Indo-German School and Workshop 2007: Neutrinos in Physics, Astrophysics and Cosmology, Mumbai, TIFR, February 16-19, 2007

55. "Leptogenesis, Dark Energy, Dark Matter, and the Neutrinos", at International Workshop in Theoretical High Energy Physics, IIT, Roorkee, March 15-19, 2007

56. "The Theory of Neutrino Masses" (3 lectures), at Joint Indo-German School And Workshop 2007: Neutrinos in Physics, Astrophysics and Cosmology, Mumbai, TIFR, February 12-23, 2007

Space and Atmospheric sciences

Ashish Dubey

57. "Heterodyne Receiver", at Microwave – 2007, AMA, Gujarat University, Ahmedabad, Jan 21, 2007

B. Bapat

58. "Photo-triple-ionisation of CO_2", at the Asian International Symposium on Atomic Physics, 4-, at Indian Institute of Technology, Chennai, 7 Dec 2006

59. "Geometry of dissociating CO_2^{2+}", at the National Conference on Atomic and Molecular Physics, at Tata Institute of Fundamental Research, Mumbai, 8-11 Jan 2007

S.A.Haider

60. "Ionospheres of Mars at low and high latitudes", at the Asia Oceanic Geosciences Society (AOGS) Annual Meeting, Singapore, 10- 14 July, 2006

61. "Chemistry and compositions of cometary coma", at the 3rd Asia Oceanic Geosciences Society (AOGS) Annual Meeting, Singapore, 10-14 July, 2006

A. Jayaraman

62. "Aerosols and their radiative forcing over India and surrounding ocean region", at the 17th mid-year meeting of the Indian academy of Sciences, IISc., Bangalore14-15 July 2006

63. "Atmospheric composition change and air quality", at the APN Scoping Workshop on South Asia Rapid Assessment Projects, Darjeeling, 8-11 Oct 2006

64. "Radiative forcing of climate - A materials perspective", at the National seminar on energy and environmental materials for sustainable development, Bengal

Engineering and Science University, Shipur, Howrah, 27-28 Jan 2007

65. "Atmospheric Aerosols", at the School on radar and lidar remote sensing of the atmosphere, SV Univ., Tirupati, 7-11 Mar 2007

66. "Greenhouse gases, Global warming and Geosphere Biosphere interactions" (three lectures) at the 5th PG course in Satellite Meteorology and Global Climate, CSSTEAP, SAC, Ahmedabad, Dec 2006

S. Ramachandran

67. "Overview of Aerosol Modeling Activities in India", at the Workshop on Atmospheric Chemistry Modeling, (CDAC), Pune, 30 Nov 2006

R. Sekar

68. "Recent advances in ESF and space weather investigations", at the National Seminar on Advances in Space Science sponsored by UGC SAP programme, Saurashtra University, Rajkot, 8 December, 2006

69. "Airglow techniques to explore upper atmosphere" (four lectures), Advanced P.G. Diploma in Space Science and its Applications, Gujarat University, 21-30 November, 2006

Shyam Lal

70. "Variability in surface ozone and related trace gases at Mt. Abu in India", at the Third APN Workshop, Yokohama, Japan, 16-18 April, 2007

71. "Atmospheric chemistry in developing India", at the Indian Meteorological Society, Pune Chapter, IITM, Pune, Nov. 21-23, 2006

72. "Characteristics of surface ozone variations at Mt. Abu", at the Second APN Workshop, NPL, New Delhi, 30th Oct.- 1st Nov. 2006

73. "Importance of trace gases in the Earth's environment", at the Seminar on Astronomy Astrophysics and Space Sciences, Department of Physics, Sardar Patel University, Vallabh Vidyanagar, 10th July, 2006

74. "Trace gases in the atmosphere", at the India-US Indo-Flux workshop, Anna University, Chennai, July 12-15, 2006

75. "Structure of earth's atmosphere (five lectures)", Advanced P. G. Diploma on Space Science and its Applications, Guj Univ., Sept. 13-22, 2006

76. "Fifth PG Course on Satellite Meteorology and Global Climate of the CSSTEAP (six lectures) SAC", Bopal, December 2006

Varun Sheel

77. "Modeling Physical and Chemical Processes in the Atmosphere", at the DST sponsered School on Atmospheric Sciences, Department of Mathematics, Bangalore University, Bangalore, 5-8 November 2006

Planex

J.N. Goswami

78. "Chandrayaan-1 Mission: An Update", International Conference on Exploration and Utilization of the Moon (ICEUM-8), Beijing, China, July 23-27 2006

N. Bhandari

79. "Lunar Exploration with Chandrayaan-1 : Adantages of Coordinated Observations With Other Missions", International Conference on Exploration and Utilization of the Moon (ICEUM-8), Beijing, China, July 23-27, 2006

80. "Lunar Exploration : Science Perspectives of Chandrayaan-1", COSPAR General Assembly, Beijing, July 16-23, 2006

81. "India's mission to moon : Chandrayaan-1", SELENE Symposium, Tokyo organized by JAXA, July 31, 2006

Planetary & Geosciences Division

R. Ramesh

82. "Recent Records of Holocene Monsoon from India and China" Golden Jubilee National Symposium on Role of Meteorology in National Development during at IITM. Pune, 21-23 November, 2006

S.V.S. Murty

83. 'Solar System Origin' at the 7th Planex workshop on "Planets, Satellites, Asteroids and Comets", held at PRL, Ahmedabad, Jan. 8-11, 2007

84. 'Evolution of Planetary Atmospheres' (four lectures) in the Winter School, "Modelling of Planetary Atmospheres" held at PRL, Ahmedabad, Dec.18, 2006 – Jan. 4, 2007

M.M. Sarin

85. "Spatiatial and temporal scale ^{234}Th : ^{238}U disequilibrium in the Arabian Sea : Implications to sinking particle fluxes", International Workshop on "Sustained Indian Ocean Biogeochemical and Ecological Research" , NIO, Goa, Oct. 3-6, 2006

86. "Reducing interferences in ICP-MS using Dynamic Reaction Cell (DRC) or Collision Cell Technology (CCT) : An Overview", DST sponsored National Training Course on "Application of ICP-MS in Earth Science System" NGRI, Hyderabad, June 2006

87. "Aerosol and Atmospheric Chemistry" (2 Lectures), Post-Graduate Teachers' Refresher Cource, Gujarat University, Ahmedabad, Febraury 2007.

A.K.Singhvi

88. "Unexplored methodological aspects and new applications of Luminescence Dating", Inaugural Key note address in the North American Luminescence meeting at USGS, Denver, USA, May, 29 2006

89. "Elnino and the Indian Monsoon", Invited talk on the Symposium on *Elnino and its paleo record* in the University of Heidelberg, Germany, Jan, 2006

90. "Chronology of past Seismic Events", National seminar on "Seismology and Paleosesimology", Inst. Seism. Res., Sept 16, 2006

91. "Luminescecne dating in Quaternary stratigraphy, tectonics and paleoseismology", Annual National Seminar of the Indian Gepohysical Union, National institute of mines, Dhanbad, Nov, 2006

92. "International year of Planet Earth: Climate and the Global change: The Indian scene", NGRI Hydrabad, Invited Presetation. Meeting of INSA sponsored meeting on International Years, October 27, 2006

93. "Instrumental, Land and Marine records of climate change : The Indian perspective ", Indo Hungarian Academies Symposium on - "Recent Earth History", INSA, Delhi, Dec 14, 2006

94. "Luminescence dating of Quaternary sediments: applications to paleoseismology and neotectonics", Colloquim at the Berkely Geochronology Centre, University of California, USA.

95. "Luminescence dating of Quaternary sequences in the Asia Pacific region: A synthesis", South Asian Luminescence Conference, Hongkong, October 23-25, 2006

96. "Luminescene dating : An example of mutualism between physics and geology", National seminar on Luminescence, Bharatiar University, Coimbatore. Jan 14-17, 2007

Sunil K. Singh

97. "Thermal Ionisation Mass Spectrometry in Earth Sciences", *12th ISMAS Workshop,* Goa, 2007

Conferences/Symposia/Workshops

Conferences/Symposia

1. A four-day **International Symposium on Quantum Optics** was held in PRL during **July 24-27 2006**, The focal themes were entanglement, quantum imaging, phase space distributions, quantum communication, nonlinear optics, BEC, coherent states, quantum-classical correspondence and revival dynamics of wave packets. The symposium had about 80 participants, from Australia, Italy, India, Japan, UK and USA. The proceedings will be released as book by Macmillan, India.

2. A Conference on **"Challenges for Solar Cycle-24"** was organized at PRL, Ahmedabad during 22-25 January 2007. This was attended by 140 participants, including 50 foreign delegates.

Workshops / Schools

1. The Fifth Postgraduate course in **Space and Atmospheric Sciences** was organized jointly with **Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP)** during **Aug 1, 2006 - April 30, 2007.** Thirteen candidates, three Indian and ten from six Asian-Pacific countries participated. The curriculum covered, Physics of Planetary Atmospheres and Ionospheres, Space Weather, Instrumentation, Space Technology, Astronomy and Astrophysics.

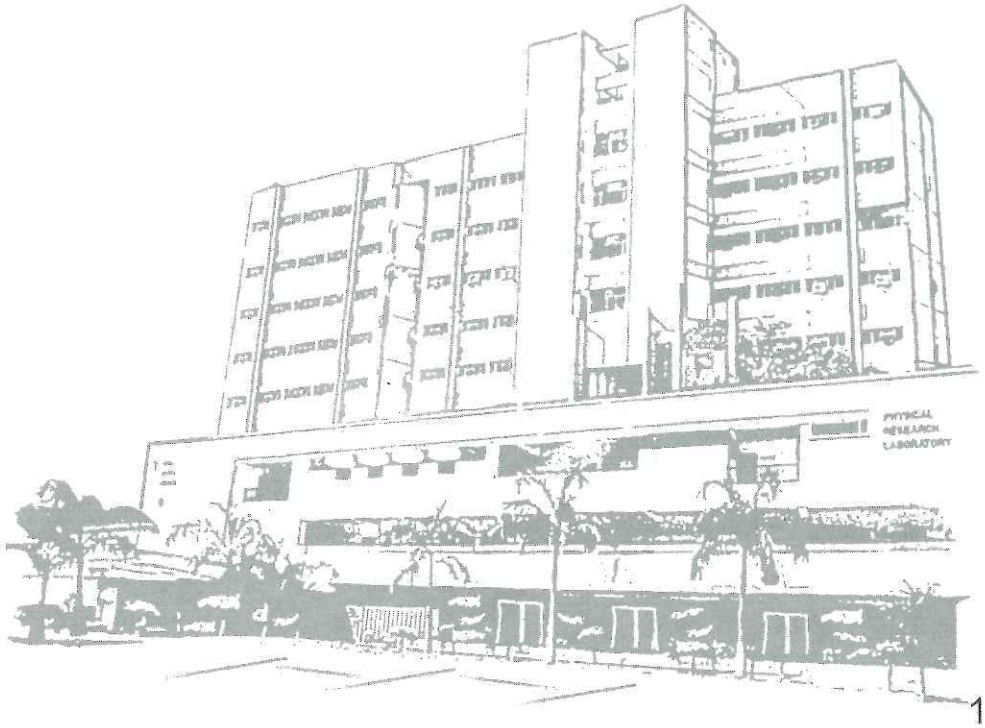
2. A Winter School on **Modeling of Planetary Atmospheres** was held during **December 18, 2006 - January 6, 2007.** Thirty five participants attended the school. The courses were on, (1) Structure and dynamics of Planetry Atmospheres, (2) Chemical, Radiation and Transport processes, (3) Solar wind interaction with planetary atmospheres, (4) Processes of airglow emissions, (5) Magnetic fields of planets, (6) Simulation of ionospheric processes and (7) Numerical analysis and mathmetical techniques.

3. **A one day Workshop on Neutrinoless Double Beta**

Deacy (NDB) on February 5, 2007 was held at PRL. This was attended by 15 active researchers to discuss important question in neutrino physics of whether neutrinos are Majorana particles, that lead to a lepton number violation in nature. This question has consequences in Astrophysics and Cosmology. In this workshop issues such as search for the neutrinoless double beta decay and the Majorana mass of the neutrinos were discussed. Lectures on different aspects of NDB, present status of all NDB experiments and developments with the Indian proposal for NDB, were presented.

4. Seventh **PLANEX workshop on Planets, Satellites, Asteroids and Coments** was held during January 8-11, 2007.

5. A workshop on **Indo-US Collaboration in Solar Physics** was held at Udaipur Solar Observatory on January 26, 2007.



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SCIENCE

Astronomy and Astrophysics

Recurrent Nova RS Ophiuchi

The well known recurrent nova RS Oph had its sixth outburst on 2006 February 2006. The previous outburst was in 1985. The distinguishing characteristics of a recurrent nova is two or more recorded nova-like outbursts, with associated increase in brightness by 100 to 10,000 times every 10 to 100 years. Recurrent novae form an exclusive subset of the cataclysmic variable class of stars of which there are only 7 confirmed members. In the visible band the magnitude of RS Oph varies from 12.5 to 4.8. Its previous 5 outbursts were recorded in 1898, 1933, 1958, 1967 and 1985. The rapid rise in brightness during such an outburst occurs within 24 hours and is followed by decay in three distinct phases lasting tens of days to hundred days.

RS Oph, is a binary system comprising a red giant and a white dwarf with 460 days orbital period. As in classical novae, outbursts of recurrent novae arise from the thermonuclear runaway on a white dwarf surface that has accreted matter from its companion star. However, there is an important distinguishing feature between the two, namely, the high velocity ejecta in a recurrent nova outburst is impeded by the surrounding stellar wind from the red giant companion leading to the generation of the shock wave. The temporal evolution of the shock wave is of considerable interest and theoretical models have been developed to study the shock wave propagation with predictions for physical parameters like shock wave velocity. The 2006 outburst of recurrent nova RS Oph provided an opportunity for testing the validity of such models.

Starting from the very next day of the outburst, an intensive observational campaign was launched at the Mt. Abu observatory. Near-infrared spectra in the 1.08 - 2.34 μm band, were measured daily for a comprehensive time series. Prominent emission lines of hydrogen, helium and oxygen were seen and all of them indicated a striking narrowing with time, implying a reduction in expansion velocity suggesting that the line emitting matter is associated with a decelerating shock wave. The theoretical studies of propagation of the shock wave in RS Oph like systems have suggested three phases, of evolution. In the first phase free expansion occurs i.e. the

ejecta expands freely into the red giant wind and produces a shock at constant velocity. Second phase is an adiabatic phase where the shocked material is very hot and in the third phase the shocked material cools by radiation. In all these phases, the time dependence of velocity was different. Our data allowed tracing the behaviour of the shock wave by estimating the widths of emission lines, both full-width at half maximum and full width at zero intensity.

Line widths of hydrogen Paschen β line at 1.1218 μm and the neutral oxygen line at 1.1287 μm are shown in Fig 1.1. The variation of the shock velocity with time is consistent with model prediction and establishes a stage of free expansion lasting about four days, during which the shock velocity remained constant. However, the decelerative phase that followed a power law; $t^{-\alpha}$. The mean value of $\alpha = 0.64$ indicate that this phase is very short-lived and suggests deviations from the model prediction.

Our estimate of ~ 3 x 10^{-6} $M_{\odot}$ for the swept up mass, implies a mass close to 1.35 $M_{\odot}$ for the white dwarf. This independent mass estimate of the white dwarf is consistent with other estimates and suggests that RS Oph is a potential Type Ia supernova candidate.

(R.K. Das, D.P.K. Banerjee and N.M. Ashok)

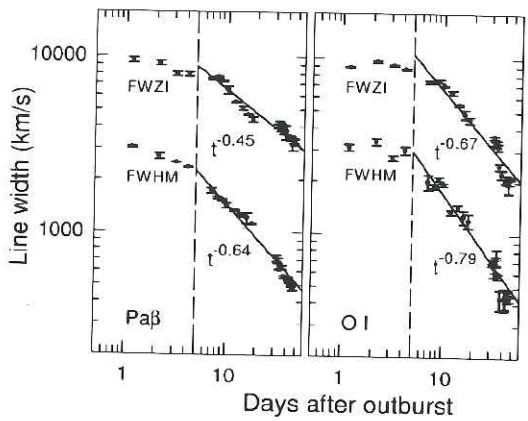


Fig 1.1 Temporal evolution of line widths for the Paβ 1.2818 μm and the OI 1.1287 μm lines. A free expansion for the infrared shock front for the first four days is seen. This is followed by a power law decline in the decelerative phase.

Infrared Spectroscopic Study of AGB and Post-AGB Stars

Near-infrared spectroscopy in H and K bands of nearly 80 AGB and Post-AGB stars at Mt. Abu Observatory using the NICMOS-3 camera/spectrograph was carried out to estimate their mass-loss rates. Archived ISO/SPITZER mid-infrared spectra were also analyzed for a few Post-AGB stars. Modeling of observed spectral energy distributions indicated interesting correlations between first and second overtone band equivalent widths of CO and mass loss indicators such as the infrared colors. The mid-infrared data, enabled identification of several polycyclic aromatic hydrocarbon molecular features in a few Post-AGB stars, indicating an advanced evolutionary stage of these objects towards becoming planetary nebulae. Mass loss rate estimates showed increasing trend with infrared colors in AGB and Post-AGB stars. Episodic mass loss was noticed in a few Post-AGB stars that showed variability on time scales as short as two months.

(B.G. Anandarao and V. Venkataraman)

Infrared study of the massive star-forming region AFGL 437

AFGL 437 is a massive star forming region at a distance of 2 kpc having compact H II regions. The surrounding reflection nebula extends to the interstellar medium. Near-infrared H and K band photometry of the object at seeing-limited spatial resolution (~ 0.5 arc sec) using WYNN 3.5m telescope at the Kitt Peak National Observatory, USA, along with archived SPITZER images in the 3.5, 4.3, 5.5, 8.5 μm bands provided evidence of several intermediate-high mass stars (up to B 0.5 spectral type) at different pre-main sequence evolutionary stages. The 8.5 μm image shows extended nebulosity surrounding the central cluster of young stars. The filamentary structure and sharp edges are suggestive of impending or on-going star formation.

(Abhijit Chakraborty, Lokesh Dewangan and B.G. Anandarao)

Optical variability in blazar 3C 279

The blazar 3C 279 is one of the most variable object in the AGN family. Historical light curves indicate that its amplitude varied over 6 magnitudes and was detected as one of the

strongest Gamma-ray emitters. In a typical outburst, the normal amplitude of variation in optical region is about 2 magnitudes. We systematically monitored this blazar from Mt Abu 1.2 m telescope in optical BVRI bands to detect micro-(intra-day) and macro-variability (short- and long-term) to understand the mechanism of emission and its structure. Observations with a 1292x1156 pixel CCD indicated that in the current outburst, 3C 279 has touched 13 mag level in R band. We also noticed intra-day (~0.06 mag) variability on some nights and a definitive fading on the longer time scale.

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

Distance and extinction estimation along a tangent to Milky Way spiral arm

Red clump (RC) in the LN45 field was used for distance and extinction estimation along the same direction in the Milky Way galaxy. The galactic coordinates of RC (l = -45deg, b= 0) point in the direction tangential to the Scutum-Crux spiral arm of the Milky Way. In this direction conventionally accepted behavior for the extinction provides a good fit to the red clump sources, only to about 3Kpc from the Sun. For distances beyond this (J magnitudes fainter than ~11) the extinction per unit Kpc varied with distance and with direction of observation. Closer to the plane, extinction per unit Kpc are much larger by a factor of nearly 3. We used the red clump sources in the 2MASS survey to estimate the extinction per unit Kpc and thus obtained the distances by assuming the detected objects to be red giants. Fig 1.2, plots the 2MASS J-Ks vs. J CMD (for l = -45 deg, b = -0.75) with the locus of the RC source at distance from 0.5Kpc onwards (blue line) with conventional (constant) extinction per unit Kpc. Green dots mark the 1, 2 and 3 Kpc points with conventional A_J value of 0.016A. Beyond 3 Kpc, the locus does not match the observed RC distribution. Assuming that the extinction per unit Kpc increases as a function of distance, it is possible to fit the observations. The red dots mark the 3,4,5,6,7,8 Kpc distance points. Therefore in direction of relatively low extinctions, it is possible go upto about 8 Kpc distance. However, close to the galactic plane (|b|<0.2) the extinction per Kpc is high such that sources only upto about 4Kpc can be detected.

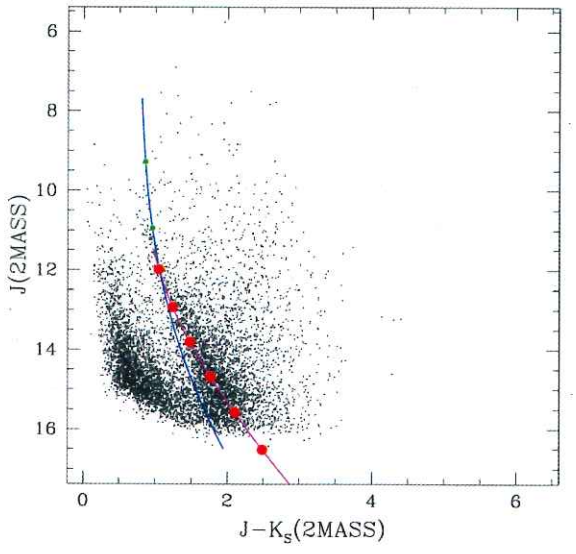


Fig 1.2 Near-infrared colour – magnitude plot of the stars in the red clump region.

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

Low Density Solar Wind Anomalies at 1 AU

Magnetic field in the heliosphere evolves in response to the photospheric field at its base. Together with the rotation of the Sun, this evolution drives space weather through continually changing solar wind and associated changing magnetic field. Although the majority of the solar sources of interplanetary disturbances could be Coronal Mass Ejection's (CME's), there are instances where they may have been caused by flare related events, transient coronal holes or outflows from active region open fields.

A detailed study of two extremely tenuous solar wind outflows, classified as "disappearance events" was carried out using ACE velocity, density and oxygen charge state ratios. These events of March and May 2003 were stable unipolar outflows with large azimuthal velocities. Both events had extended beyond Alfven radii that became independent of magnetic field. This suggests a solar origin in active region with open fields located at central meridian. Since active regions on the Sun are often ignored as a source for the interplanetary magnetic field at 1 AU, this work highlights the role of stable and unipolar outflows from the Sun, possibly from small transient coronal holes or active region open fields, that may cause such unusual, long lasting density depletions in the solar wind at 1 AU.

(P. Janardhan)

Flux Limits on the detection of Ultra High Energy Cosmic Rays (UHERC) from the moon using the GMRT

The study of the cosmic rays whose energies are above the GZK cut-off energy of 5×10^{19} eV is of great theoretical interest. Cosmic ray particles cause electromagnetic cascades in dense media, thereby produce strong coherent pulses of Cerenkov radiation at radio wavelengths. The radio transparent lunar regolith, extending about 20m below the surface of the moon is an ideal target for studying such high energy cosmic rays. The absence of an atmosphere implies that electromagnetic showers in the lunar regolith would be caused by the primary cosmic ray particles.

We explored the possibility of detection of UHECR radio waves from the moon with the Giant Metre Radio Telescope (GMRT). The GMRT currently operates in 8 frequency bands around 150, 235, 325, 610 and 1000-1450 MHz. With an effective area of 30000m^2 at frequencies up to 327 MHz and 18000m^2 at higher frequencies, the rms sensitivity of the GMRT is 0.3 mJy and 0.03 mJy at 327 MHz and 1.4 GHz respectively. With such high sensitivity, a substantial improvement in the measurement of the UHECR radio waves from the moon and a lowering of the bounds on the UHECR fluxes on the moon, is expected.

(P. Janardhan and S. Mohanty)

Space weather consequences of extremes of solar events

Flares are short lived extreme events that take place on the Sun. The other extreme situations deal with solar wind. These are of two types - in the first case, the solar wind velocity and density are much lower than normal, and can lead to movement of the magnetopause boundary as much as 20 R_e (R_e : Earth radii). In the second case, the solar wind velocity and density are much higher than normal. Several such extreme cases have been observed by satellite and indirect IPS observations. These are found to be normally associated with coronal mass ejections (CMEs). The dynamical pressure of the solar wind could increase by as much as 100 nPa in these cases and the magnetopause gets compressed. However, the compression is not directly proportional to the increase in pressure. We investigated several of these extremes for their effect on geomagnetic indices. It was found that both the type of extremes create geomagnetic effect of varying quantity. It is however difficult to make a direct and quantitative relationship of the observed effects to any of the two types of the extremes.

This work was done in collaboration with RAC, Ooty and the Physics department of SU, Rajkot.

(Hari Om Vats, Som Kumar Sharma and Harish Chandra)

Interplanetary shocks

The ACE satellite has been at the L1 point for almost 10 years, and the SWEPAM and MAG instruments are constantly monitoring the interplanetary medium. The data from these instruments have been used to identify interplanetary shocks. More than 600 interplanetary (IP) shocks have been identified and characterized during 1997 – 2006. We tried to investigate the relationship of IP Shocks with frequency of occurrence of the sunspot number. The study shows that annual sunspot number and the corresponding total IP shocks during the year have a linear relation (cross correlation coefficient ~ 1). On the other hand, monthly occurrence frequency of the interplanetary shocks shows a very poor correlation with the sunspots number. At zero lag, the values of cross correlation is less than 0.2 for all the years (1998-2006) whereas the annual data gives cross correlation of 0.96 for the zero lag. This establishes that it is possible to predict the total number of IP shocks in a year, but no predictions are possible at short time scales of months, weeks and days. This implies that the mechanism of IP shock generation has an annual memory, (Fig 1.3)

(Hari Om Vats)

Rotation of Sun and its atmosphere

Solar rotation is a phenomenon known for more than a few centuries. However, experimental observations and modeling of this phenomenon remains a challenging task. We obtained a long time series of radio data at 2800 MHz for the period 1947 to 2005 and derived the coronal rotation epoch for over four solar cycles. Similar analysis scheme is being used to study the solar rotation as a function of latitude on solar surface and height in the solar atmosphere. For this, solar images at different wavelengths, such as Radio, H-alpha etc. were used.

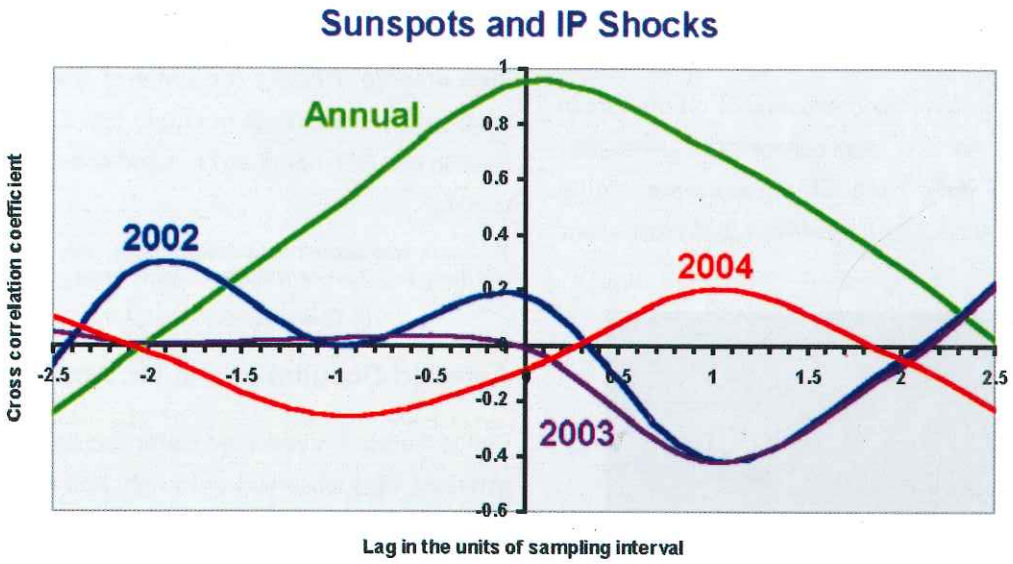


Fig. 1.3 Variation of cross correlation coefficient as function of lag in the units of sampling interval for the data. Sampling interval for annual (green curve) is one year and that for curves in blue, violet and red, for the monthly data of years 2002, 2003 and 2004 respectively, is one month.

These were treated as tracers to obtain information about different layers of solar atmosphere. H-alpha images of the chromosphere for the period Jan – June 2000, were analyzed statistically and the sidereal rotation period was obtained as a function of latitude. Sunspots were used as tracers, and the estimated rotation period for 20° S, 10° S, 10° N, 20° N & 30° N were 27.0, 25.2, 25.0, 25.6 & 26.2 days, respectively. For comparison, the radio-heliographic images of the corona at 17 GHz for the same period (Jan – June 2000) were analyzed. This led to the estimation of sidereal rotation period at 20° S, 10° S, 20° N & 30° N latitudes as 27.0, 22.4, 23.4, & 26.2 days respectively. These results suggest similar rotation periods for both wave lengths. More detailed and long term analysis of this data is in progress.

This work is done in collaboration with Dr Mehul Mehta (VP Science College Vidyanagar, Gujarat) and Mr. Satish Chandra (SHD College Sitapur, UP)

(Hari Om Vats)

Smart 1 Lunar Impact Observational Campaign

European Space Agency's (ESA's) first technology mission to the moon, Smart 1 impacted on the lunar surface on Sept. 03, 2006. A global observational campaign was organized by ESA to observe and study the energetics of the impact. As the orbit of Smart 1 was gradually decaying with perilune (point in the orbit nearest to the moon) changing only by 400 m from one orbit to next, there was a real possibility of the impact taking place during an orbit before or after the nominal orbit. Due to this possibility the impact time had an uncertainty of ±7 hours. The expected region of impact on the moon (34° S, 44°.2 W) was monitored at Mt. Abu Observatory (24° 39' 10" N, 72° 46' 47" E, 1680m) on the night of Sep. 02, 2006. A video rate CCD system attached to a 20cm f/6.3 telescope was used. The data recorded at a frame rate of 25 frames/s was stored in a video tape with a precise time information. Two time slots of observations coincident with orbits 2887 and 2888 of Smart 1 were made:

1. 14 : 00 UT - 14 : 50 UT
2. 17 : 30 UT - 19 : 15 UT (till Moon set).

The sky conditions were good. If the impact had occurred over Indian longitudes it would have been recorded. The final impact however occurred over American longitudes and the impact flash was observed from a telescope in Hawaii.

(T. Chandrasekhar, N.M. Ashok, N. Bhandari and S.N. Mathur)

Estimation of coronal temperature during the total Eclipse of 2001

The Fabry-Perot Interferometric experiment on the Green coronal line during the total solar eclipse of 21 June 2001 provided a large data base of 17 separate digital interferograms. Recently using IDL software, 500 radial scans

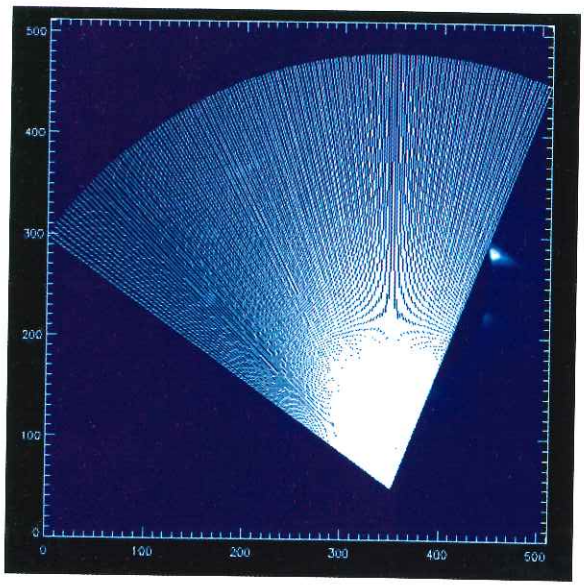


Fig. 1.4 Minutely spaced radial scans from the fringe centre across the solar corona. Line profiles are generated at points of intersection of radial scans with the fringes of the interferogram from which coronal temperatures are estimated.

(Fig. 1.4) from fringe centre were carried out in one of the interferograms. Each scan contains several fringes which have to be individually analyzed to derive line/continuum ratio, line width temperature and Doppler velocities at the position of the fringes in the solar corona. A global structure of the temperature and velocity field of the corona of that day can then emerge. Results for some of the scans suggest temperature in the range of (1.0 to 3.7) x 10^6 K for coronal position with R/R_o from 1.057 to 1.360 and azimuth from 71.4° to 304.2°.

This work was carried out in collaboration with Prof. Jay Pasachoff and Terry-Ann Suer of Williams College, Mass., USA.

(T. Chandrasekhar, N.M. Ashok and B.G. Anandarao)

Asteroid Occultations at Mt. Abu Observatory

During the last few years five stellar occultations by main belt asteroids were observed at the Mt. Abu Observatory. The observations were in the J band (1.2 microns) and were carried out using the NICMOS IR camera in the sub array mode. As per the predictions, most of these events were near the centre and the derived chord lengths provide a direct estimate of the projected size of the asteroids. It has been possible to compare these values with radiometric diameters derived from the IRAS data base. The radiometric method is based on finding a diameter and albedo that will match the observed reflected and thermal emission from the body and is model dependent. Chord lengths derived by us match well with the indirect IRAS diameters except in case of 11 Parthenope. This could be due to a non-central event.

At the request of French astronomers at Meudon Observatory observations of a rare event – a possible stellar occultation by satellite (Romulus) of a main belt asteroid 11 Sylvia (predicted to happen near Gurushikar) were attempted. The star was monitored under clear skies but the event could not be seen at Gurushikar.

(T. Chandrasekhar, R.R. Shah and S.N. Mathur)

Solar Physics

Detection of "Doppler Ribbons" Associated with an Intense 4B/X17 Flare

H-alpha flare ribbons are the sites of impact of electron beam on chromospheric material and show enhanced brightening in H-alpha wavelengths. Signatures of the electron beam impact were seen at enhanced levels in the "super active region" NOAA AR 10486 which appeared on October 28, 2003 and produced a lot of space weather related activity. An interesting photospheric phenomenon, viz. "Doppler ribbons" or localized velocity enhancements, was seen to accompany the H-alpha ribbons during the X17 flare of October 28, 2003 in SOHO/MDI. The dopplergrams overlaid with contours of H-alpha brightness (Fig 2.1) clearly show enhancements of velocity signals which exactly match the H-alpha brightness enhancements in space, and are delayed by approximately 1 minute in time. These observations can be explained in terms of a shock (generated by electron impact in the chromosphere) that travels downward towards the photosphere. Assuming that the shock travels with the speed of sound (~ 7 km/s), the time lag of ~ 1 min implies a height of ~ 500 km of the evaporation site above the photosphere. This coincides with the base of the chromosphere. These observations and the excitation of 3 min oscillations by this flare (reported earlier) suggest that the Doppler ribbon is a manifestation of a pressure impulse striking the photosphere, following explosive evaporation in the chromosphere. The fact that these Doppler ribbons are not observed commonly also indicates that the electron flux from the flare must be extraordinarily large to be able to produce a discernible effect in the photospheric Doppler signal.

This work was done in collaboration with Wahabuddin of ARIES, Nainital, India.

(P. Venkatakrishnan and Brajesh Kumar)

Magnetic and Velocity Field Variations in Solar Active Regions

The magnetic and velocity field evolution in the two magnetically complex active regions NOAA 10486 and NOAA 10488 observed during October-November 2003 studied.

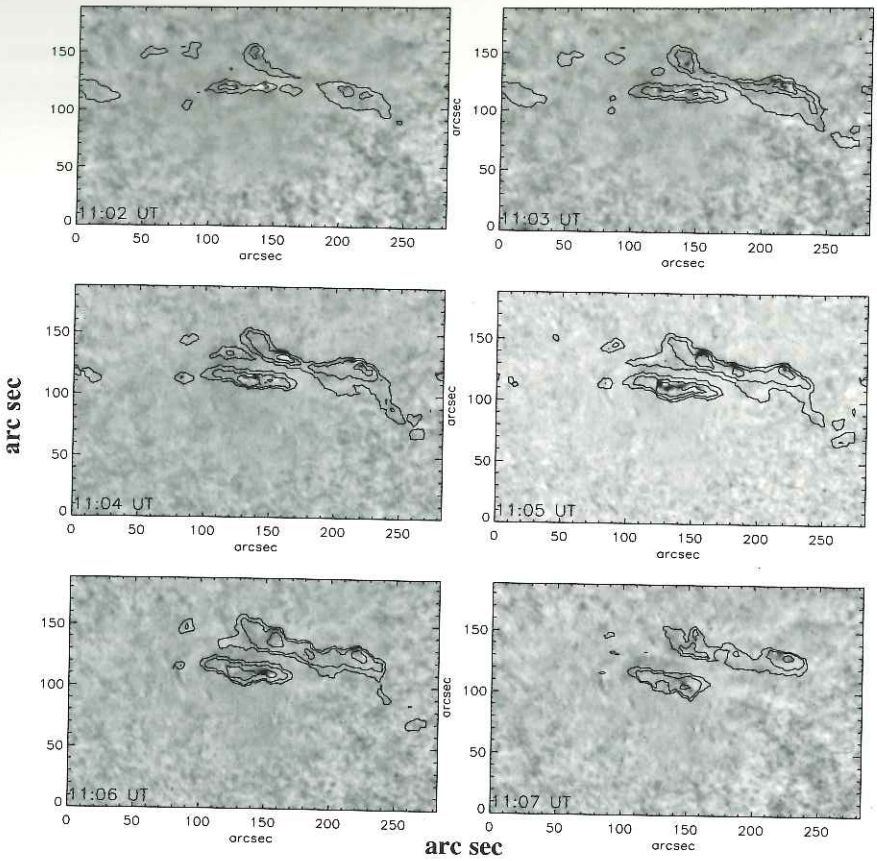


Fig. 2.1 Sequence of SOHO/MDI Dopplergrams showing the evolution of photospheric velocity enhancements during an X17 flare in the active region NOAA 10486 on October 28, 2003 between 11:02-11:07 UT. Overlaid on these Dopplergrams are H-alpha flare intensity contours observed during the period. The contours are drawn at levels of 40%, 60%, and 80% of the peak value in H-alpha intensity. It is observed that the photospheric velocity enhancements in the active region during the aforesaid "super-flare" appear in the form of "Doppler ribbons" and follow the H-alpha flare ribbons with time.

We used the available data to examine net flux and Doppler velocity time profiles to identify changes associated with evolutionary and transient phenomena. A correlation (~40%) between the net magnetic flux time profiles of NOAA 10486 and 10488 was found on October 28, 2003, suggesting an interconnection between these two active regions. This is further corroborated by SOHO-EIT images showing the interconnection through a trans-equatorial loop. Both gradual evolutionary, and abrupt flare associated changes in net area-averaged magnetic flux are observed in several locations in NOAA 10486 during the X17/4B super-flare of October 28, 2003. Interestingly, a rapidly moving feature was observed from the GONG+ (and SOHO-MDI) movies of magnetograms, originating from the flare site, and propagating as a wave (Fig. 2.2). Its estimated speed ~40 km/s is much larger compared to the usual ribbon-separation speed of 3-10 km/s in two-ribbon flares, but similar to that of the seismic waves (~45 km/s) reported earlier by Kosovichev and Zharkova. The exact nature of this feature needs further investigation.

(Ram Ajor Maurya and Ashok Ambastha)

Chromospheric and Photospheric Magnetic Shear in a Solar Active Region

Magnetic shear in the solar active region NOAA 10935 and in its next appearance as NOAA 10941 were examined. The chromospheric chirality was seen in H-alpha images while the photospheric shear was seen in vector magnetograms taken from Udaipur Solar Observatory (Fig. 2.3). It was seen that the direction of the photospheric transverse field was aligned with the super-penumbral H-alpha filaments. We calculated the helicity for both the active regions and identified the chirality of the associated filaments. We also used the chirality of H-alpha structures for resolving 180^0 azimuthal

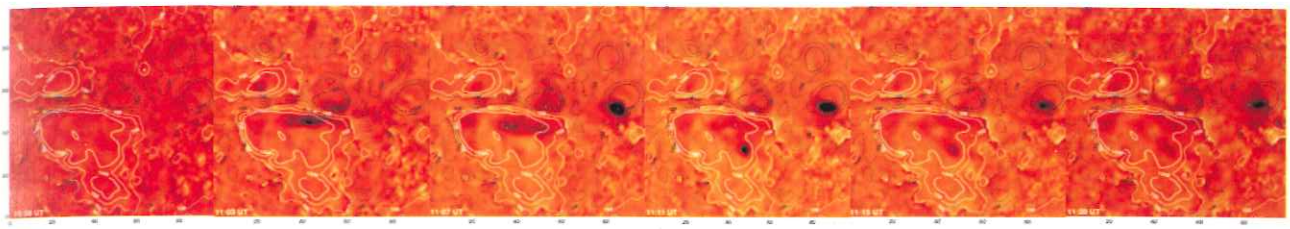


Fig. 2.2 : Evolution of magnetic fluxes and the moving feature observed during 10:59-11:15 UT seen in difference images $I_t - I_{10:55}$

ambiguity in the transverse field of the vector magnetograms.

(Sanjiv Kumar Tiwari, Jayant Joshi, Sanjay Gosain and P. Venkatakrishnan)

Hα Intensity Oscillations in Large Flares

The problem of Hα intensity oscillations in large flares, particularly, those classified as X-class flares, has been reinvestigated. We have used high spatial and temporal resolution digital observations made at Udaipur Solar Observatory during the period 1998-2006 and selected several events based on suitable selection criteria. Normalized Lomb-Scargle periodogram method for spectral analysis of time-series with unequal temporal sampling was used to study the oscillatory power in quiet and active chromospheric locations, including the flare ribbons. Preliminary Results from the analysis of the six Hα flares are

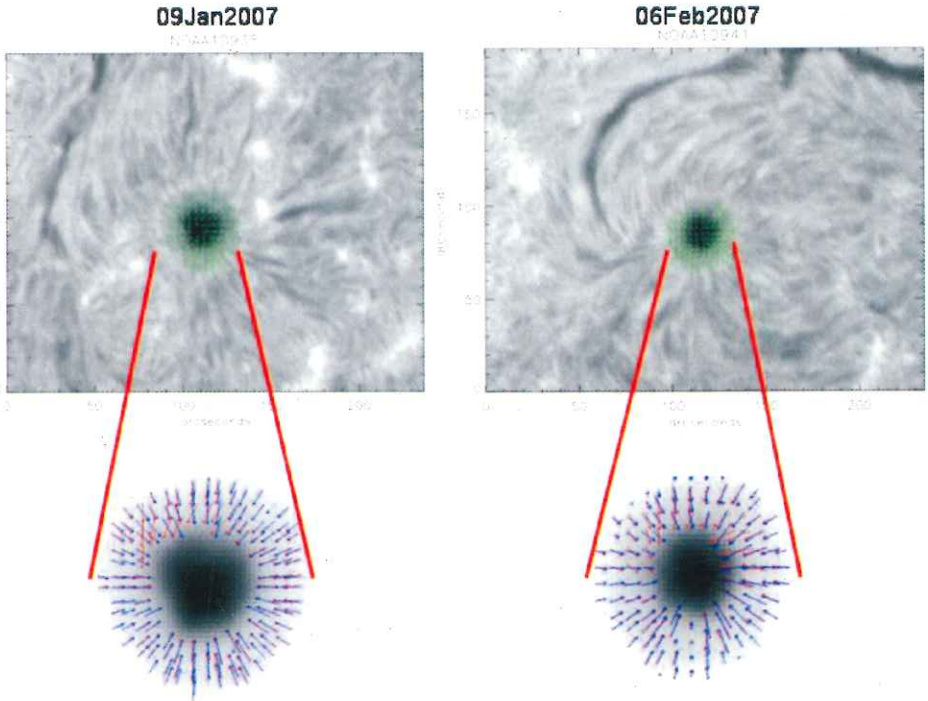


Fig. 2.3 : Vector magnetograms of a sunspot during two passages across the solar disk on 9 January (left) and 6 February (right) 2007 superposed on H-alpha pictures taken during the same time at the spar telescope at USO. It can be seen that the vector field closely matches the H-alpha fibrils

not conclusive and do not consistently provide the expected 3 and 5 minute oscillations at various locations. We plan to enhance our sample of flares by including M-class flares of significant importance in optical Hα class, i.e., 1B and larger, in order to increase the statistical significance of the results obtained in this study.

(Ram Ajor Maurya and Ashok Ambastha)

Improved Space Weather Prediction Model

A previously developed logistic-regression model for predicting space weather based on solar and interplanetary variables associated with geo-effective CMEs was refined using obser-vations of geo-effective CMEs observed during the last 10 year period i.e. 1996-2006. The new model demon-strated improved prediction (71%) for the superintense events i.e. those CMEs which resulted in Dst index < -200 nT as compared to the previous model. This is attributed to the occurrence of large number of super-intense events during 2003-2006. The model was also used to estimate the relative importance of each solar and interplanetary parameter for the prediction of major geomagnetic storms. We found that the prediction is not very successful based on only solar parameters thereby implying that more work is required for identification of crucial solar parameters that control the geo-efficetiveness of CMEs. Work on a more rigorous model is currently in progress.

(Nandita Srivastava)

Solar Vector Magnetograph

The Solar Vector Magnetograph (SVM) was made operational during 2006-07 after completing the following activities, (a) Fabrication of new opto-mechcanical mounts : filter trolley for simultaneous observations in two wavelengths was developed with a motorized translation stage. A monolithic mount for Fabry-Perot etalon, collimating lens, re-imaging lens was fabricated for preventing relative misalignments in collimation. Polarization analyzer calcite crystals were mounted on 5-axis positioning system for better alignment and were put in an enclosure to prevent stray light entering into the optical system; (b) Installation of new German-Equatorial Mount. A new robotic (fully computerized) telescope mount was procured for SVM. The installation of the optical rail of SVM on the new mount was carried out. The mount itself was installed and polar-aligned at the island site. Several modifications of the software were carried out for automating data acquisition and control of SVM. The instrument became operational in February 2006.

(Sanjay Gosain and P. Venkatakrishnan)

Dual Beam Hα System for Space Weather Studies

A new instrument with a dual-beam Hα Doppler system is being developed in order to improve the quality and quantity of data on quiet, active and erupting filaments and prominences on the Sun, especially those associated with geo-effective coronal mass ejections. These data can be potentially used to construct three dimensional topology of erupting filaments as they leave the surface of the Sun and can be compared with multi-wavelength data from space missions such as STEREO, SOHO, and Solar B. In the proposed dual-beam instrument, the 1Å interference filter centered around Hα directly images the Sun on to a CCD camera, and serves as a blocking filter for a narrow-band lithium niobate Fabry-Perot (FP) etalon in the second beam. This will record the narrow band images at different spectral positions along the line profile with another CCD camera Fig. 2.4. The FP can measure velocities ranging from -150 to +150 km s^{-1}. This technique would enable us to record fast erupting solar events which leave mid-area of the Sun so that their effects at Earth can be anticipated 1-5 days in advance.

We have developed a 16-bit D to A converter and the required software program for tuning the FP. Characterization of FP and prefilter are being carried out using a spectrograph. A high sensitive temperature controlled oven has also been constructed for the FP, as the refractive index of $LiNbO_3$ is sensitive to temperature with a change of 1 °C producing a wavelength shift of 100 mÅ. The newly built temperature controlled oven has been able to maintain a stability of 0.0625 °C, that corresponds to wavelength shift of 6 mÅ.

This work was done in collaboration with Sara F. Martin of Helio Research, USA.

(Nandita Srivastava, Shibu K. Mathew and Sudhir Gupta)

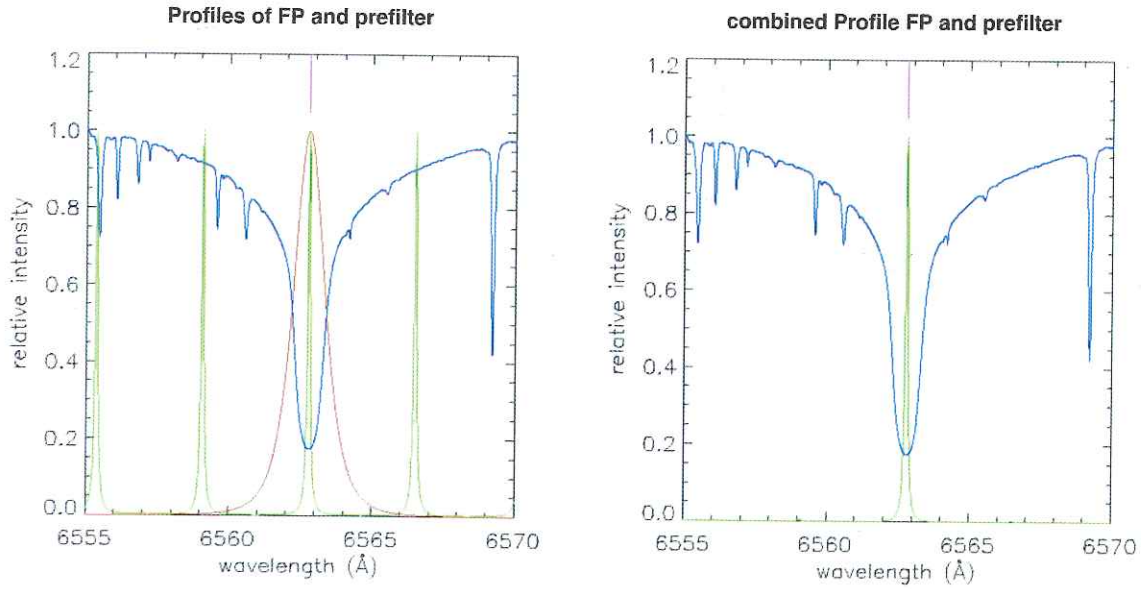


Fig. 2.4 : Theoretical wavelength profiles of pre-filter and the Fabry Perot etalon

Development of a Solar Adaptive Optics system

Development of Solar Adaptive optics system (AOS) at Udaipur Solar Observatory is nearing completion. The correction of the simulated distortions has been demonstrated using a laboratory source. The simulated system is able to create only systematic distortions and they are corrected successfully. The same has to be repeated for distortions that are random in nature, as is the case for an extended source like Sun, for complete realization of the AOS. The components used for laboratory demonstration of AOS are: a He-Ne laser source; two deformable mirrors (DM), one for creating distortion and other for correction; a tip-tilt mirror for correcting the global tilt of the distorted wave-front and a lens-let array with a fast camera as a sensing element (Fig. 2.5). During the process, the tools such as on-line generation of influence matrix, mapping of the DM actuator space with sensor are developed and are ready to be used.

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

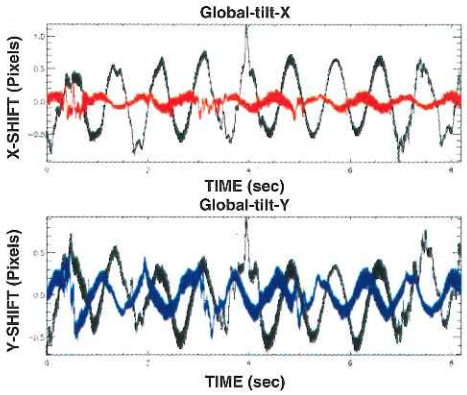


Fig. 2.5 : Improvement in the correction of the simulated distortion of the wavefront using a P-Controller with P=10. The black lines show the global-tilt of the wavefront before correction along x- and y- directions, whereas the colored ones are after correction.

Fe and Fe/ Ni Line Features in Solar flare X rays

We carried out a study demonstrating that the high resolution spectra of solar flares in the energy range 4-20 keV may be better fitted with the multi-thermal power-law plus non-thermal assumptions instead of previously considered isothermal assumption. This analysis led us to derive the abundance ratio of Fe to Fe/Ni line features in solar flare, relative to coronal abundance, based on 243 X-ray spectra of 14 M-class solar flares observed by "Solar X-ray Spectrometer" (SOXS) – Low Energy detector (SLD) payload that employs SiPIN and CZT detectors. The sub-keV energy resolution of the Si PIN detector allowed a study of the Fe-line and Fe/Ni line features in greater detail with the application of multi-thermal diagnostics. The abundance ratio of Fe to Fe/Ni-line features reduces

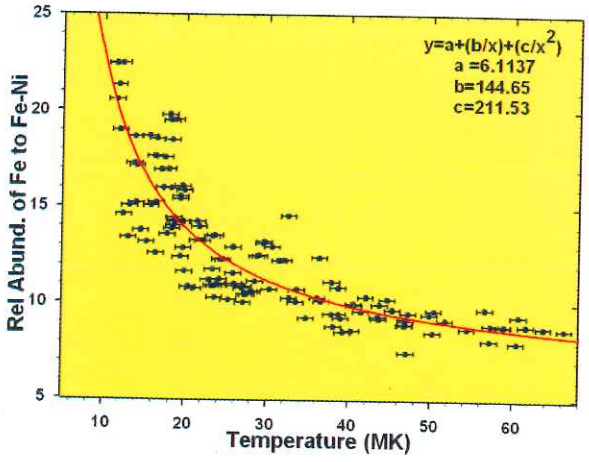


Fig. 2.6 : Ratio of coronal abundance of Fe to Fe/Ni line features as a function of electron temperature measured during solar flares observed by SOXS mission.

exponentially as a function of electron temperature. (Fig 2.6). This explains the variation of equivalent width and peak energy of these features with temperature.

This work was done in collaboration with Brian R. Dennis and Richard Schwartz from NASA Goddard Space Flight Center, Greenbelt and Anil K. Pradhan from the Ohio State University, Columbus.

(Rajmal Jain and Raghunandan Sharma)

Dynamics of small-scale phenomena on the Sun

Multi wavelength observations of small scale processes in sunspots were made at Sac Peak observatory, NSO, USA, in visible waveband with the application of G-band (4305 Å) and Universal Birefringent Filter (UBF). Our study shows that G-band bright points are co-spatial and co-amorphous with magnetic elements in intergranular lanes. It appears that micropores and pores are formed by the accumulation of magnetic elements at a flow-field sink. Spatially narrow but strong downflow of material is observed at the edge of magnetic structures, such as small flux concentrations, micropores and pores. Narrow (<0.25) filament channels of downflowing plasma were observed. Up-flow and down-flow were found in magnetic bright points and filament channels while micropores and pores showed only upflow. The time-lapse observations made using high order adaptive optics (AO) enabled us to study the high spatial, temporal and spectral resolution filtergrams. We studied intensity and velocity oscillations in small scale flux concentrations and found high frequency halos around strong flux concentrations (pores) and in intermediate field strength network. This is a manifestation of mode conversion of solar p-modes in magnetic fields. Detection of opposite polarity in a light bridge with respect to parent sunspot umbra, was a new observation made during this study. Appearance of surges and Ellerman bombs near and over the light bridge (Fig. 2.7) imply that low-altitude magnetic reconnections can occur in the magnetic cancellation region.

Analysis of high resolution Dopplergrams and continuum images of the active region also enabled us to measure the upward velocity of the order of 400 ms^{-1} within umbral dots (UDs), surrounded by downward velocity of the order of 300 ms^{-1}, (Fig.2.8). This observation provides clear evidence for a convective origin of the umbral dots.

This work was done in collaboration with Thomas Rimmele and R. N. Smartt from National Solar Observatory, New Mexico, USA and S. N. A. Jaaffrey and Lokesh Bharti from M. L. Sukhadia University, Udaipur.

(Rajmal Jain)

Measurement of Break Energy between Thermal and Non-thermal processes operating in Solar Flares

X-ray spectra of 9 intense flares observed by SOXS during 2004-05 were examined. Combining 4-25 keV and 4-55 keV spectra for the flares under consideration, we first derived the temperature and emission measure of these flares, and found

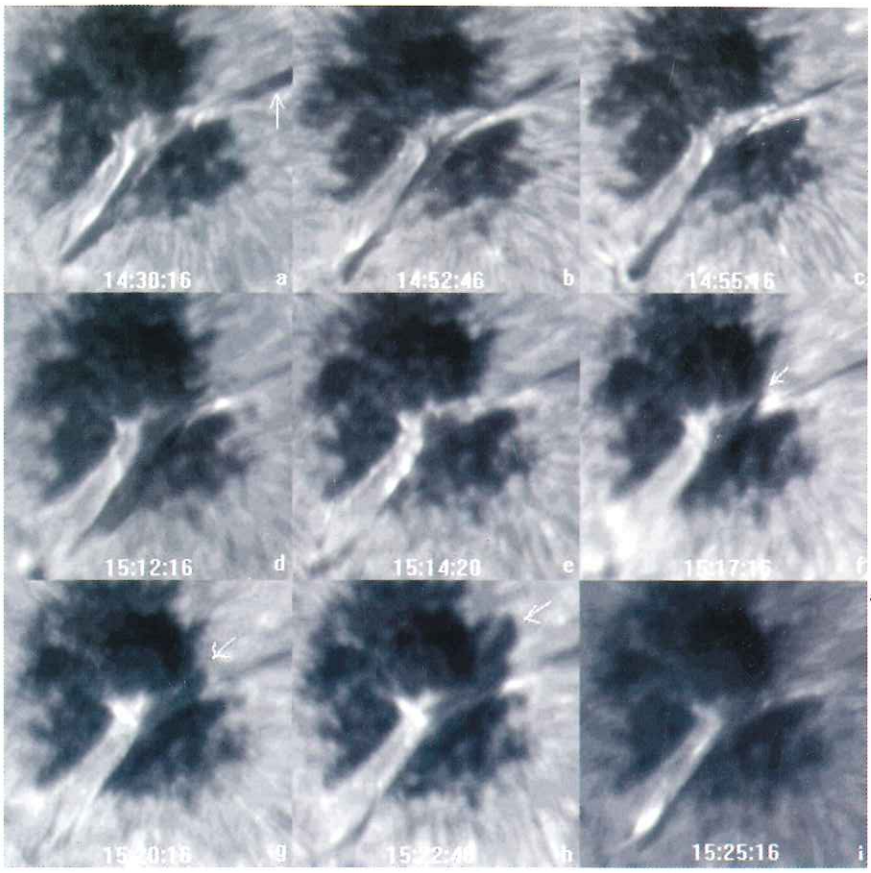


Fig.2.7 : Ellerman bombs and surges over the light bridge and near to lower left arm edge in H α -700 mÅ.

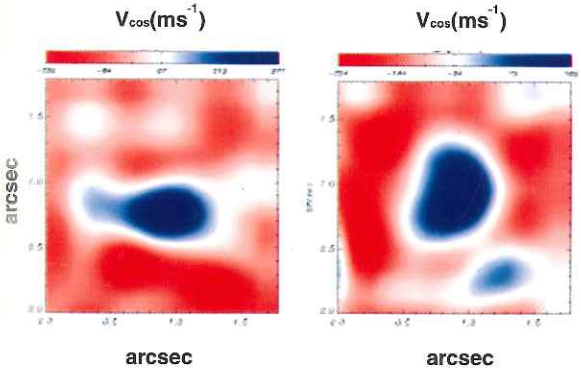


Fig.2.8 Line-of-sight velocity in a central umbral dot (CUD-left) and peripheral umbral dot (PUD-right). In CUD upflow (blue) may be noted in the center whose magnitude is reducing towards outer side. Narrow downflow (red) channels adjacent to upper and lower edges of the UD are unambiguously evident. In PUD, the upflow is seen in the center but the narrow down-flow channels are evident in right and left side. Two small UDs may be noted around this PUD with relatively small upflow.

that temperature follows the same evolution as intensity over time. However, in order to fit the spectra in high energy we used broken power law function to identify the break energy distinguishing the thermal from non-thermal processes. The observations from the CZT detector enabled measurement of the break energy with an accuracy of ±1.8 keV. We found that the evolution of break energy also follows the change in temperature. This indicated that the non-thermal processes operate only in the early growth phase of the flare, and with increase in temperature, the low energy cut-off of non-thermal energy also moves to higher side (Fig.2.9). However, the emission measure does not vary significantly during the main phase of the flare development.

(Rajmal Jain and Raghunandan Sharma)

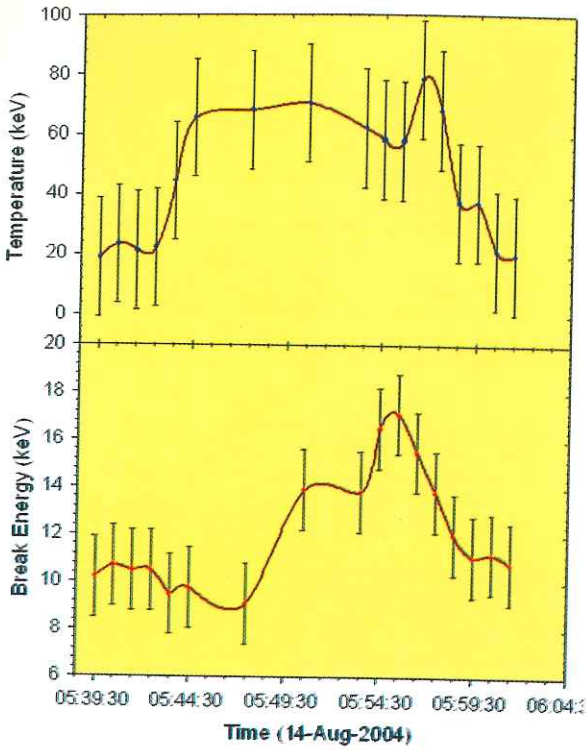


Fig.2.9 : Measured peak temperature assuming multi-thermal plasma and break energy between thermal and non-thermal spectrum as a function of time on 14 August 2004 flare.

Dynamics of CMEs associated with Impulsive and Gradual Solar Flares

Study of Coronal Mass Ejections (CMEs) associated with impulsive and gradual flares is under progress. The impulsiveness of a flare has been identified on the basis of its rise time and peak count rate in 10-20 keV energy band. Appropriate association of flare and CME has been carried out using SOXS and GOES light curves, EIT and LASCO/SOHO images. Dynamics and energetics of CMEs have been investigated with respect to the impulsiveness and plasma properties of the respective associated flare. Study of a total 21 CMEs-flare associated events during 2004-05 showed that CMEs associated with impulsive flares with velocity in general <1000 km/s have positive acceleration. The mass of the ejecta is between 10^{12}-10^{14} kg and the kinetic energy range between 10^{25}-10^{30} ergs. On the contrary, the CMEs associated with gradual flares have velocities in the range 200-2000 km/s and negative acceleration. The mass and kinetic energy carried by them range between 10^{12}-10^{16} kg and 10^{25}-10^{32} ergs, respectively. CMEs associated with gradual flares often trigger interplanetary Type II radio bursts. We are comparing soft and hard X-ray emission parameters of the flares with dynamics of associated CMEs in order to understand its origin

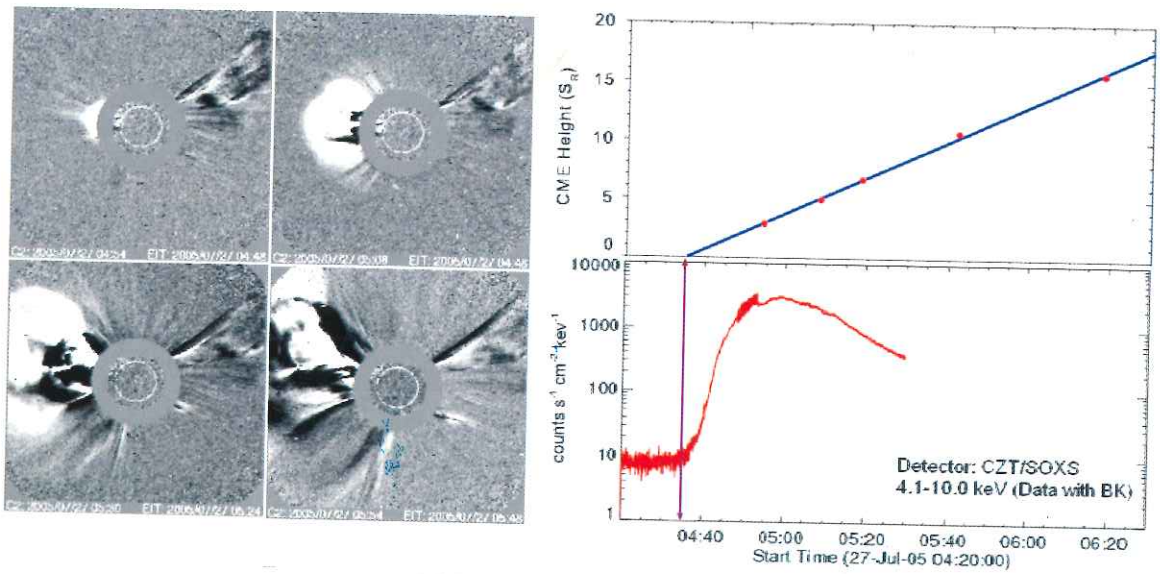


Fig. 2.10 : Sequence of difference images of coronal mass ejection observed by C2 LASCO instrument onboard SOHO spacecraft (left) and CZT/SOXS light curve with propagation of CME (right) showing initiation of CME at lower corona.

and initiation. The difference images of a halo CME observed on 27 July 2005 by C2 instrument of LASCO onboard SOHO mission shown in Fig. 2.10 where the CME's propogation and its propagation is compared with onset of soft X-ray emission. It appears that CME might have initiated around 04:36:55 UT with a linear speed of ~1787 km/s.

This work was done in collaboration with P. G. Kulkarni from Z. B. Patil College, (North Mahrashtra University) Dhule and A. P. Mishra and Meera Gupta from A. P. S. University, Reewa, M. P.

(Rajmal Jain and Raghunandan Sharma)

Theoretical Physics

Implications of A_4 Symmetry

The discrete symmetry A_4 was used to understand structure of neutrino masses. This symmetry had earlier been used in several different context. We proposed a novel assignment which leads to neutrino mass matrices with two zeros (two elements with zero values) in their structure. This leads to several predictions which are studied in detail. It is shown that many of the predictions of the A_4 scheme can be understood as arising from a much smaller Z_3 symmetry.

This work was carried out in collaboration with M. Hirsch, S. Kaneko and J.W.F. Valle of University of Valencia.

(A.S. Joshipura)

Spontaneous CP Violation and Complex CKM Matrix

Recent experimental findings in B physics have been used to argue that the Cabibbo-Kobayashi-Maskawa (CKM) matrix is complex. This goes against the fundamental ideas of spontaneous CP violation and natural flavour conservation. We proposed an alternative in which, the symmetry leading to natural flavour conservation is replaced by a generalization of the $\mu - \tau$ symmetry used to understand the atmospheric mixing angle. This change allows spontaneous CP violation, complex CKM matrix and generates suppressed flavour changing neutral currents which can be looked for. Predictions of such currents in B physics are worked out in detail.

(A.S. Joshipura and Bhavik P. Kodrani)

Correlations from New Physics with Polarized Beams at the Linear Collider

The issue of the discovery of new physics at high energies associated with the proposed International Linear Collider in the presence of longitudinal and transverse electron and positron beam polarization were examined. The beam polarization dependence and the angular distribution were determined. Also computed was the final state polarization of a particle of spin half in a one-particle inclusive final state produced in e^+e^- collisions (through the interference of the amplitude of γ or Z, with the amplitude from new interactions having arbitrary space-time structure). We also determined

the angular distribution of two particles and its dependence on the beam polarization, thus extending our earlier work. Our work provides an approach for model-independent determination of the space-time structure of beyond the standard model interactions. We briefly discuss applications of the framework to popular extensions of the standard model, and demonstrate that our framework is general enough to account for certain results in the minimal supersymmetric standard model.

This work was carried out in collaboration with B. Ananthanarayan from IISc, Bangalore.

(S.D. Rindani)

Top polarization and CP properties of Higgs in $e^+e^- \to t\bar{t}H$

In extensions of the standard model, like the two-Higgs doublet models, that include the minimal supersymmetric standard model, the Higgs can be CP even or CP odd. In these two cases, the couplings to fermions differ. We investigated the use of top polarization in the process of associated top pair and Higgs production at a linear collider to determine the CP properties of the Higgs. We also considered a general case when the Higgs is not a CP eigenstate and show that top polarization and the azimuthal asymmetries of the Higgs can be useful probes of the CP properties of the Higgs.

This work was carried out in collaboration with S. Bhupal Dev from IISc, Bangalore; A. Djouadi from Lab. de Physique Theo. Orsay; R.M. Godbole from. IISc, Bangalore and M.M. Muehlleitner from Lab. d'Annecy Phys. Theo. , Annecy, France.

(S. D. Rindani)

Cosmological constant and neutrino masses

At present all astrophysical observations together indicate that about 70% of the total matter density of the universe is in the form of dark energy or cosmological constant. When written in terms of some mass scale, this corresponds to fourth power of 0.01 eV. In particle physics all the phase transition scales which can contribute to the cosmological constant are much higher. For example, if the electroweak symmetry breaking scale contributes to the cosmological constant, it would be 52 orders of magnitude larger than what is observed. Since the only physics we know around 0.01 eV is the neutrino mass, a connection between these two completely diverse phenomena have been proposed. The triplet Higgs model, proposed by us in the past, could be extended to bridge these two phenomena.

This work was done with Prof. E. Ma, Univ. of California at Riverside, USA.

(Utpal Sarkar)

Anomaly and Extra Dimensions

Anomaly is a mathematical concept, which appears in some models of field theory. If any theory has non-vanishing anomaly, then any symmetry of the classical theory will be broken when quantum corrections are included. So, any consistent gauge theories should be free of anomalies in four and higher dimensions. In the four dimensions, anomaly appear as triangle fermion loop, with external gauge boson legs. In any theory the sum over all the fermions should cancel all the diagrams. In higher dimensions there will be square or pentagon anomalies, making the group theory factor more and more complicated. However, for any consistent phenomenological models of extra dimensions this anomaly cancellation has to be checked. We developed a simple algorithm to calculate the group theory factor entering in anomalies in four and higher dimensions for the groups SU(N) and SO(N) in terms of the Casimir invariants of their maximal subgroups following a method developed by Wigner. This can have applications in formulating consistent models of extra dimensions.

(Utpal Sarkar)

CP violation and Leptogenesis

We have seen CP violation in the weak interactions in the quark sector coming from the quark mixing matrix. Although we have not evidenced any other CP violation, we would like to know if there are other sources of CP violation. In cosmology, the evolution of the universe also requires CP violation to explain why there is more matter compared to antimatter in the universe. A popular explanation for this asymmetry associates this problem with the neutrino masses. The mechanism is known as the leptogenesis. We tried to understand the question of CP violation entering in the neutrino masses and leptogenesis. There are now several CP violating phases, which can enter in the different processes in different

combinations. We tried to relate the CP violating phase in leptogenesis to the CP violation that may be observed at low energy.

(Utpal Sarkar, K. Bhattacharya, N. Sahu and S. Singh.)

Gravitino production in an inflationary Universe

The cosmological consequences of gravitinos generated in the early universe are proportional to their number density. The gravitino number density is usually calculated in the radiation dominated era following inflation. We calculate the gravitino number density produced during reheating at the end of inflation and find that it is comparable to the number density generated in the radiation dominated era after reheating. This lowers the bound on the reheat temperature, relevant for leptogenesis and GUT baryogenesis models, by a factor of 4/3.

(R. Rangarajan and N. Sahu)

Features in the Primordial Spectrum from WMAP: A Wavelet Analysis

Measurements of the anisotropies in the cosmic microwave background enable us to recover the primordial power spectrum for a given set of cosmological parameters. We use Discrete Wavelet Transform to decompose the local features of the recovered spectrum individually to study their effect and significance on the reconstructed angular power spectrum and hence, the likelihood. We show that besides the infra-red cut off at the horizon scale, the associated features of the primordial power spectrum around the horizon have a significant effect on improving the likelihood. The strong features are localised at the horizon scale.

This work was carried out in collaboration with A. Shafieloo and T. Souradeep of IUCAA, Pune

(P. Manimaran, R. Rangarajan, P. K. Panigrahi)

Entanglement Induced Sub-Planck Structures

Sub-Planck structures may arise in the phase space when well separated coherent states are superposed. Such states provide high sensitivity and they are suitable to carry out Heisenberg limited measurements. We examined Wigner function of a system describing entanglement of two cat-states. It has been demonstrated that Quantum interference arising from entanglement produces sub-Planck structures in the phase-space plots of the Wigner function. Origin of these structures in our case depends on entanglement. It is argued that the entangled cat-states are better suited for precision measurements.

(J.R. Bhatt, P. K. Panigrahi and M. Vyas)

Quantum Entanglement: Separability Conditions for a Continuous Variable

Quantum entanglement is a unique resource for quantum computation, quantum cryptography, teleportation etc. To know whether a given quantum state is entangled or not is an important question. But a rigourous answer to this question is not available, and, for a continuous variable it is still an open question. For most experimental situations one often deals with quantum states with continuous variables. We developed a criterion for separability to test the entanglement for continuous variable states using statistical methods. The criterion can be applied to any form of the continuously variable state. This is an important improvement over the previous results where the separability conditions for Gaussian states have been worked out.

(J.R. Bhatt and P. K. Panigrahi)

Quantum Ratchets with Chaotic Systems

Ratchets are devices that preferentially allow directed motion in the absence of a net bias in the system. One common example is the turnstiles that would allow people to go only one way. During the past decade, inspired by many biological phenomena where molecules apparently climb up the potential barriers, many ratchet properties have been studied. These exploit Brownian noise to create directed motion. We examined a particle in a finite well system which is kicked by a laser pulse. By breaking appropriate spatio-temporal symmetries, we show that directed current can be obtained in such a system. These are examples of coherent, noise-free ratchets. This can be experimentally realized using cold atoms in an optical lattice and experiments of this nature are already in progress elsewhere.

(Harinder Pal and M. S. Santhanam)

Synchronous Extinction of Species

Over 99% of the species that ever existed on the surface of

the Earth are now extinct and their extinction on a global scale has been a puzzle. One may think that a species under an external threat may survive in some isolated locations leading to their eventual revival. Using a general model we show that, under a common external forcing, the species with a quadratic saturation term first undergoes spatial synchronization and then suffers extinction. The effect can be observed even when the external forcing acts only on some locations provided the dynamics contains a synchronizing term. Absence of the quadratic saturation term can help the species to escape extinction.

This work was carried out in collaboration with G. Rangarajan from IISc, Bangalore)

(R. E. Amritkar)

Analysis of Embedded Gaussian Orthogonal Ensemble of Random Matrices

For the realistic one plus two-body embedded Gaussian orthogonal ensemble of random matrices with spin [EGOE(1+2)-s], the inverse participation ratio (a measure of chaos), is calculated for 6, 7 and 8 fermion systems with good total spin S. Propagation equations for fixed-spin spectral variances explain the numerical results. Similarly, lower order correlations between spectra with different particle numbers and spins are analyzed using fixed-spin energy centroids and spectral variances. The correlations are small for low-spin members. In this work, analytical formulas for cross correlations are derived for the first time. Analytical formulas are also derived for the simpler spinless EGOE. Most importantly, these cross correlations form a definite signature of EGOE as they are zero in the standard GOE random matrix description of the states of a many fermion system.

This work has been done in collaboration with N.D. Chavda of Nirma Univ. and R. Sahu of Belhampur Univ.

(V.K.B. Kota)

Wigner-Racah Algebra for Embedded Gaussian Unitary Ensemble of Random Matrices

It is proved that exact results for embedded Gaussian unitary ensemble of two-body interactions for fermions with spin [EGUE(2)-s] can be obtained using the Wigner-Racah algebra of the embedding $U(2\Omega) \supset U(\Omega) \otimes SU(2)$ algebra. Explicit formulas, for systems with m fermions and spin S, are derived for the lower order cross correlations, between states with (m,S) and (m',S'), generated by this ensemble and also, in terms of a $SU(\Omega)$ Racah coefficient, for the fourth order shape parameter with fixed -(m,S) density of states.

(V.K.B. Kota)

Regular Structures in Random 2 and 3-Body Interactions

Several new examples for energy centroids generated by random 2 and 3-body interactions are studied by deriving propagation equations for the centroids defined over extended group symmetries of the shell model (SM) and the interacting boson models (IBM) of nuclei. In IBM, with 3-body interactions, the examples are:

(i) $U(6) \supset SU(3)$ of sdIBM-1;

(ii) $U(18) \supset U(6) \otimes [SU(3) \supset SO(3)]$ of sdIBM-3.

Similarly in SM, with 2-body interactions, the examples are:

(i) $U(24) \supset [U(6) \supset SU(3)] \otimes SU(4)$ in(2s1d)shell;

(ii) $U(n\Omega) \supset [U(\Omega) \supset SO(\Omega)] \otimes SU(n)$,

n=2,4. Isospin centroids in SM with 3-body interactions are also analyzed. All these examples confirm that random interactions generate regular structures as seen in the ground state region of nuclei.

(V.K.B. Kota)

Statistical Spectroscopy for Neutrinoless Double-Beta Decay

Neutrinoless double-beta decay (NDBD) half-lives combined with the corresponding nuclear structure matrix elements (NSME), calculated using nuclear model, give a value/bound for neutrino mass. A new method for NSME based on statistical nuclear spectroscopy is being developed by recognizing that the NSME can be written as square of a two-body operator, defined by the so called 'neutrino potential'. With this, NSME is written in terms of a bivariate density. The moments of this density are traces of some operator products. Similarly the

statistical spectroscopy method for the closely related double GT strength sums is also written down. Propagation equations for all the needed traces are being worked out so that the new method can be applied to real nuclei.

This work was done in collaboration with V. Potbhare from M. S. Univ., Vadodara; K. Kar from SNIP, Kolkata and R.U. Haq from Leaurentian Univ. of Sadbury, Canada.

(V.K.B. Kota)

Quantum Optics & Quantum Information

Coherent control of solitary waves

We present a large family of exact solitary wave solutions of the one-dimensional Gross-Pitaevskii equation, with time-varying scattering length and gain or loss, in both expulsive and regular parabolic confinement regimes. The consistency condition governing the soliton profiles is shown to map onto a linear Schrödinger eigenvalue problem, thereby enabling one to analytically deduce the effect of a wide variety of temporal variations in the control parameters that are experimentally realizable. Corresponding to each solvable quantum mechanical system, a soliton configuration can be identified. These include soliton trains in close analogy to experimental observations of Strecker et al. [Nature (London) 417, 150 (2002)], spatitemporal dynamics, solitons undergoing rapid amplification, collapse and revival of condensates, and analytical expression of two-soliton bound states. This approach also works for modified KDV equation.

This work was done in collaboration with R. Atre and G. S. Agarwal from Oklahoma State Univ., USA.

(P. K. Panigrahi)

Soliton Solutions of Driven Non-linear Schrödinger Equation

The structure of the exact, dark and bright soliton solutions of the driven nonlinear Schrödinger equation were analyzed. A wide class of solutions, phase locked with the source, are identified for distinct parameter ranges. These contain periodic as well as localized solutions, which can be singular implying extreme increase in intensity. Conditions for obtaining non-propagating solutions are also derived. A special case, where the scale of the soliton emerges as a free parameter, is obtained. Stability analysis is also carried out through the Crank–Nicolson method.

This work was done in collaboration with T. Soloman Raju from BITS Pilani and C. Nagaraja Kumar from Punjab University.

(P. K. Panigrahi, Vivek M. Vyas)

Coherent Control of Solitons in Strongly Coupled Cigar Shaped Bose Einstein Condensates (BEC)

Soliton solutions of strongly coupled Bose-Einstein condensates and their coherent control in the presence of a harmonic trap is demonstrated analytically. In particular, a soliton solution with W type density profile, well suited for trapping of neutral atoms, is found whose minima locations can be precisely controlled. Soliton complex, containing a singular soliton exhibiting matter wave self-focusing, as also bright solitons are obtained as exact solutions in the attractive regime.

(P. K. Panigrahi and Utpal Roy)

Exact and Approximate Wave Functions of Hooke's Atom

An algebraic procedure was used to find exact and approximate eigenstates of two-charged particles in an oscillator potential. Relationship of this system with the quasi-exactly solvable ones was utilized to develop a perturbation theory, involving the Coulomb coupling. Single particle densities, for arbitrary m and information entropy densities were analytically obtained.

This work was carried out in collaboration with C. S. Mohapatra from IIT Kharagpur.

(P. K. Panigrahi and R. Atre)

Spectral fluctuation characterization of random matrix ensembles

A recently developed wavelet based approach is employed to characterize the scaling behaviour of spectral fluctuations of random matrix ensembles, as well as complex atomic systems. Our study clearly reveals anti-persistent behaviour and supports the Fourier power spectral analysis. It also finds evidence for multi-fractal nature in the atomic spectra. The multi-resolution and localization nature of the discrete wavelets ideally characterize the fluctuations in these time series, some of which are not stationary.

This work was done in collaboration with P. Anantha Lakshmi from University of Hyderabad.

(P. K. Panigrahi and P. Manimaran)

Entanglement by linear SU(2) transformations

We consider the evolution of a two-mode system of bosons under the action of a Hamiltonian that generates linear SU(2) transformations. The Hamiltonian is generic in that it represents a host of entanglement mechanisms, which can thus be treated in a unified way. We start by solving the quantum dynamics analytically when the system is initially in a Fock state. We show how the two modes get entangled by evolution to produce a coherent superposition of vortex states in general, and a single vortex state under certain conditions. The degree of entanglement between the modes is measured by finding the explicit analytical dependence of the Von Neumann entropy on the system parameters. The reduced state of each mode is analyzed by means of its correlation function and spatial coherence function. Remarkably, our analysis is shown to be equally as valid for a variety of initial states that can be prepared from a two-mode Fock state via a unitary transformation and for which the results can be obtained by mere inspection of the corresponding results for an initial Fock state. As an example, we consider a quantum vortex as the initial state and also find conditions for its revival and charge conjugation. While studying the evolution of the initial vortex state, we have encountered and explained an interesting situation in which the entropy of the system does not evolve whereas its wave function does (Fig. 3.1). The proposed approach is equally applicable for a two-particle system in which each particle is represented by its bosonic creation and annihilation operators.

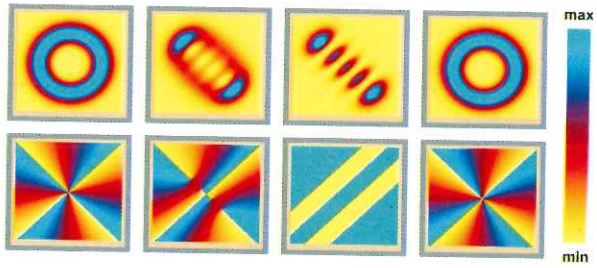


Fig. 3.1 : The intensity (top row) and the phase (bottom row) of a quantum vortex of matter or light changing with time even though the entropy of the system remains constant. Note that the direction of phase change in the last column is reversed with respect to the first as the initial vortex transforms to its complex conjugate.

(G. S. Agarwal and J. Banerji)

Fundamental mode only propagation in Highly Multimode Fibre

The use of short lengths of large core phosphate glass fibre, doped with high concentrations of Er or Er:Yb represents an attractive route to achieving high power erbium doped fibre amplifiers (EDFAs) and lasers (EDFLs). With the aim of investigating the potential of achieving diffraction limited output from such large core fibres, we present numerical simulations and experimental results of fundamental mode propagation through a 20 cm length of passive 300 μm core multimode fibre when the input is a well-aligned Gaussian beam. The fibre had a numerical aperture of 0.389, implying a V number of 236.8 and was capable of supporting in excess of 28000 ($\sim V^2/2$) modes. To our knowledge, this is the largest core fibre through which diffraction limited *fundamental mode propagation* has been demonstrated. Although the results presented here relate to undoped fibre, they do provide a practical basis for generation of new EDFAs and EDFLs.

This work was done in collaboration with C. D. Stacey and R. M. Jenkins, QinetiQ, UK and A. R. Davies, Royal Holloway, University of London, UK.

(J. Banerji)

Optical Vortices Produced by Forked Holographic Grating and Sign of their Topological Charge

The field associated with the vortices, manifestation of phase singularities characterized by topological charges, possesses a helical wavefront. The direction of circulation of this wavefront around the phase singularity defines the sign of topological charge associated with the vortex. We produce optical vortices using a computer generated hologram (CGH) employing a forked grating and propose to use free space trajectory of the vortex produced for assigning sign to topological charge associated with the vortex. We find experimental trajectory of the vortex that matches with theoretical trajectory for both negative and positive charges

obtained with Collins integral formalism for vortex propagation. This match is used to unambiguously determine the sign of the vortex charge.

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

Propagation of Axial and Non-axial Vortex

Before using an optical vortex for any application, it is important to know if the vortex is axial or non-axial. This is because the properties of one type vortex are different from the other. Continuing our work on the Wigner function of an optical vortex, we show experimentally and theoretically that the Wigner function can be used to discriminate between vortices. We use transport properties of the Wigner function to study the propagation characteristics of an axial and non-axial vortex and find them to be different.

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

LOFF Condensate in Non Commutative Field Theories

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

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

Fermion Pairing in Cold Atoms

The phase diagram of non relativistic fermionic system in an atomic trap with imbalanced population numbers with a four fermi interaction is investigated using a variational approach. Depending upon the interaction strength the system can be in normal state, in fully gapped BCS state, gapless breached paring state or in a state with a finite momentum condensate.

This work is being carried out in collaboration with Amruta Mishra, IIT Delhi.

(H. Mishra and Bhaswar Chatterjee)

Color Superconductivity with Magnetic Field

We study color superconductivity in presence of a magnetic field which could be relevant for physics of ultracompact astrophysical objects like neutron stars. Two flavor color superconductivity is studied with a variational ansatz state having pairing between quarks of different flavor, spin and color in the lowest Landau level. The Gap equation is derived in presence of external magnetic field. Abelian magnetic field seems to enhance the color superconducting gap.

This work is being carried out in collaboration with Amruta Mishra from IIT Delhi.

(H. Mishra and Bhaswar Chatterjee)

Space and Atmospheric Sciences

Effect of Convection on Tropospheric Ozone Distribution

Vertical distribution of ozone in the troposphere is highly variable due to chemical and transport effects. Measurements of vertical distribution of ozone, temperature and humidity over the Bay of Bengal (BOB) and the Arabian Sea were made as a part of the 'Integrated Campaign for Aerosols, Trace Gases and Radiation Budget (ICARB)' during March-May, 2006. Ozone distribution was measured using balloon-sondes, a standard chemical technique, launched together with radiosondes. During the entire campaign, 29 balloon launches were made. A low value of tropospheric column ozone (22.4 DU) was observed on March 30, 2006 over the central BOB as compared to the average column ozone of 36.7 DU over this region (Fig. 4.1). The vertical distribution of ozone shows lower ozone up to about 6 km height. The meteorological conditions indicate existence of strong convection during this period over this region.

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

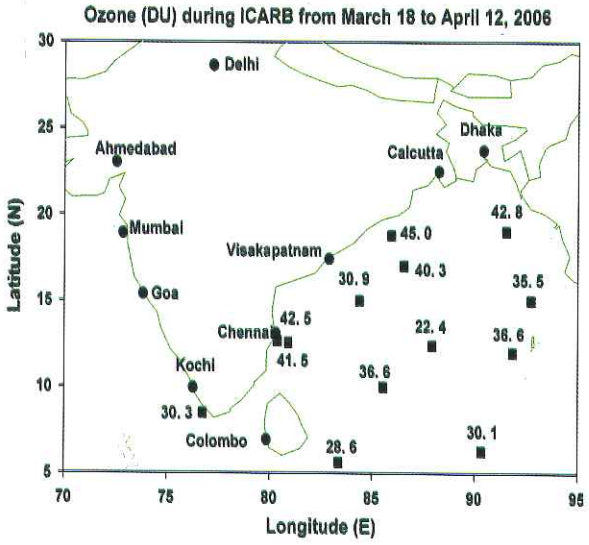


Fig. 4.1 : Integrated tropospheric ozone in Dobson Unit (DU) observed during the ICARB campaign from March 18 to April 12, 2006 over Bay of Bengal.

Variation in Ozone Concentrations over Coastal and Marine Regions

As a part of ICARB, air-borne studies from Bhubaneswar, Chennai, Trivandrum and Goa were conducted using a National Remote Sensing Agency's aircraft. A total of 26 air sorties were made in different directions at 2 levels viz., 500 m and 1500 m at some locations and at 8 levels between 500 m and 3000 m at other locations. Ambient level ozone concentrations were measured using an online ozone analyzer. During the East-West sorties, ozone concentrations at 500 m and 1500 m levels, at Chennai are shown in (Fig. 4.2). The

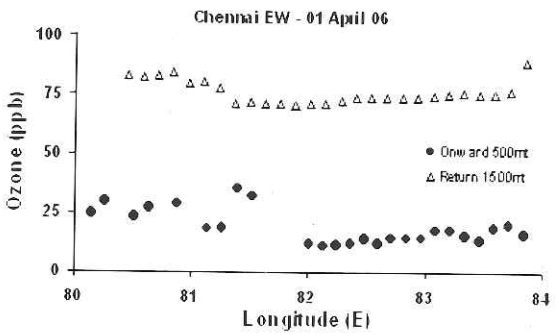


Fig. 4.2 : In situ ozone mixing ratios (in ppbv) measured at two heights during the East-West transect of the flight from the Chennai airport on April 1, 2006.

average ozone concentration at 1500 m is higher than at 500 m. Change in the boundary layer height in moving from over the land to the marine region is seen at both the levels.

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

Aerosol Asymmetry Parameters in the Lower Troposphere

Air-borne measurements of aerosol scattering coefficients (total and backscatter) were performed using an integrating nephelometer at 450, 550 and 700 nm at 8 heights in the 0 to 3000 m region over Bhubaneshwar, Chennai, Trivandrum and Goa during March-May 2006. Asymmetry parameter g profiles in the lower troposphere were derived from this data set. On

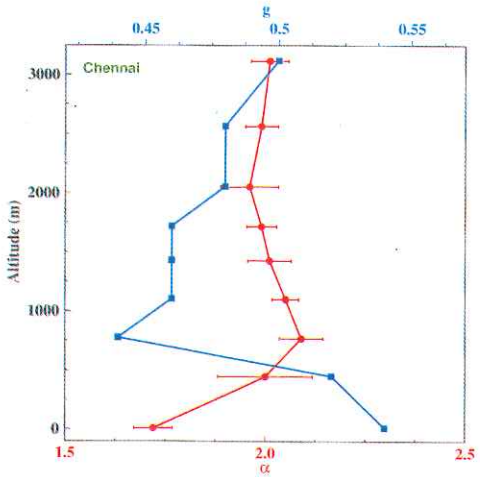


Fig. 4.3 : Vertical profiles of Angstrom exponent α and asymmetry parameter g determined from airborne measurements of aerosol scattering coefficients over Chennai.

an average, the scattering coefficient (b_{sca}) values (corrected with relative humidity) in the east (Bhubaneshwar, Chennai) were twice the values in the west (Trivandrum, Goa). In the lower troposphere the ratio of $b_{backsca}$ to that of b_{sca}, was > 0.13. Angstrom wavelength exponent α, varied from 1.70 to 2.09 in these four locations. The values of α over these regions in India are lower than the values over Southern Great Plains of USA, Bondville and Sable Island. These suggest dominance of larger size aerosol particles. The value of g, at 550 nm was in the 0.3-0.6 range over India. Profiles of α and g obtained over Chennai were anti-correlated (Fig. 4.3). Lower α values arise due to increase in the number of larger aerosols, which affect b_{sca} more at longer wavelengths than at smaller wavelengths.

(S. Ramachandran and T.A. Rajesh)

Aerosol Radiative Forcing on the Climate over South Asia

Effects of aerosol radiative forcing on the South Asian climate were examined using the state-of-the-art Regional Climate Model (RegCM3) of the Abdus Salam International Centre for Theoretical Physics, Italy (ICTP). Radiative transfer schemes were the same as the NCAR global model CCM3 and included 18 spectral intervals from 0.2 to 5 mm. RegCM3. includes all major aerosol species and different transport processes. Simulation domain for the study covered entire south Asia,

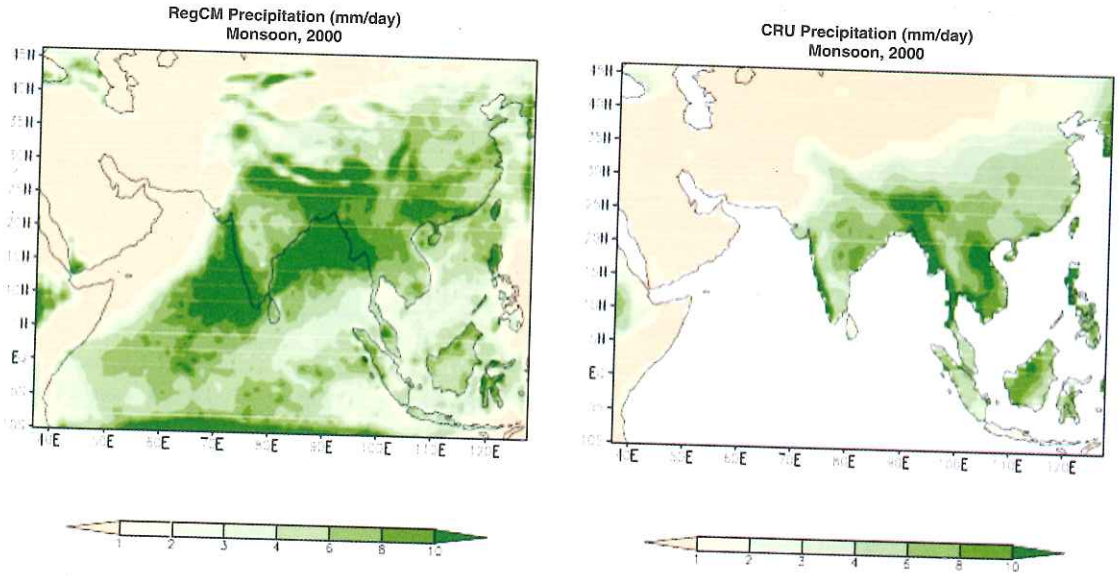


Fig. 4.4 : Results from the simulation show the presence of a large atmospheric dust burden over the Taklamakan desert in China, which gets distributed over the northern slopes of Himalayas and parts of the Tibetan plateau.

parts of east Africa and the Arabian Peninsula. A horizontal resolution of 90 km and 18 vertical levels were kept. We conducted simulations for six years from 2000 to 2005 with an initial spin-up time of two months. The meteoro-logical boundary conditions required to drive the model were obtained from the NCEP re-analyses data. In the control experiment, no aerosol forcing was included while in the anomaly experiments, radiative forcing were included for dust aerosols in four different size bins. In order to validate the model performance we compared our simulation results with observational data obtained from Climate Research Unit (CRU), USA, for the monsoon season of year 2000. (Fig. 4.4)

(D. Ganguly and A. Jayaraman)

Validation of MODIS derived Aerosol Optical Depth over Ahmedabad

Inversion procedure for the retrieval of aerosol properties from satellites includes several assumptions. These procedures need validation with the ground truth. Aerosol properties over Ahmedabad were compared with data from the Moderate Resolution Imaging Spectro-radiometer (MODIS) sensor onboard the NASA satellites Terra and Aqua. Aerosol Optical Depth (AOD) showed considerable differences, which were ascribed to the underlying surface reflectance properties. The recently updated MODIS AOD product includes the angular and seasonal variations of surface reflectance. Comparison of updated product and the ground truth data indicated substantial improvement over the initial version. The differences can be attributed to the aerosol models used in the retrieval algorithm. Proper account of the aerosol parameters obtained from 4 years of aerosol observations over Ahmedabad has improved the correlation over this region.

(Amit Misra, Dilip Ganguly and A Jayaraman)

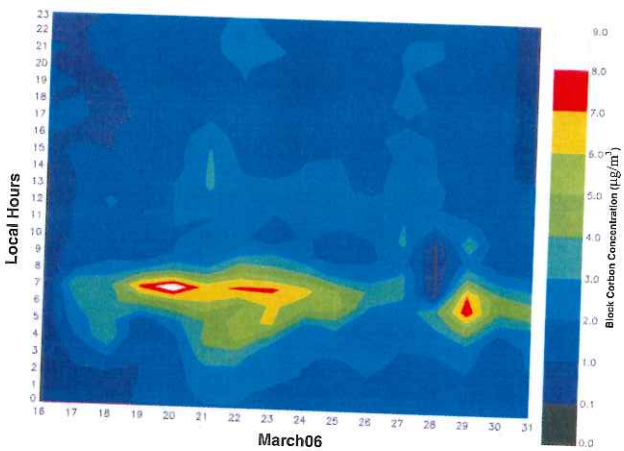


Fig. 4.5. Diurnal variation of the black carbon concentration observed at Kalpakkam. High BC concentration is observed during morning hours when the land breeze prevails.

Diurnal Variation of Black Carbon Concentration at Kalpakkam

One of the major anthropogenic components of the atmospheric aerosols is black carbon (BC) or soot particles, mainly released from incomplete combustion of carbon-based fuels. BC has high absorbing efficiency for both the incoming solar and the outgoing longwave radiation. During March 2006, simultaneous measurements of BC concentration (Fig. 4.5) and other aerosol parameters were made at Kalpakkam (12.56°N, 80.12°E). The concentration is high (3-8μg/m^3) during morning hours when the land breeze prevailed. Higher BC amount during evening hours has been reported from inland stations like Ahmedabad, Delhi, Kanpur etc. This was however absent over Kalpakkam due to the prevalence of sea breeze during evening that brought relatively pristine air to the measurement site. On 20-27th March 2006, the BC concentration was high during sea breeze period. This was explained by using 7-day air back-trajectory analysis, which indicated their source from the Indo-Gangetic plains. BC values were < 3μg/m^3, when the air parcels came from the Indian Ocean or the Arabian Sea.

(Sanat Kumar Das and A. Jayaraman)

Aerosol Optical Depths over Bay of Bengal and the Arabian Sea during Pre-Monsoon Season

In situ AOD in the 0.40 to 1.05 μm wavelength region over Bay of Bengal (BOB) and Arabian Sea (AS) were measured during March-May 2006 onboard Sagar Kanya cruise. The mean AOD (0.36) over BOB was higher than that over the AS (0.26) at all wavelengths. Daily mean AOD at 0.55 μm over BOB and AS analyzed from MODIS satellite data were 0.27 and 0.23 respectively. MODIS derived fine mode fraction was found to be higher (0.79) over BOB compared to the AS (0.70). The mean Angstrom exponent, α, over BOB was higher at 1.12 compared to 0.73 for the AS. Turbidity coefficient β for BOB and AS were 0.15 and 0.16 respectively. The observed variations in AODs were further analyzed using 7-days back trajectory analyses at six different heights. The higher AODs obtained (for example, on 24 March, 2006) was due to the influence of air masses originating from the densely populated and industrialized eastern and central Indian regions. The anthropogenic influence in the AODs over BOB and the AS was greater than 60%.

(Sumita Kedia and S. Ramachandran)

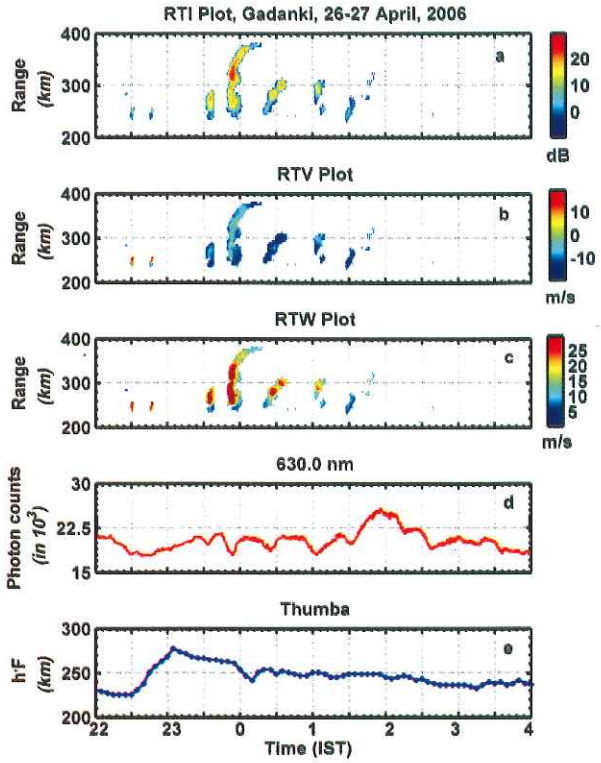


Fig. 4.6 : Equatorial Spread F (ESF) structures on April 26, 2006 as revealed by (a) Range-Time-Intensity (RTI) plot, (b) Range-Time-Velocity (RTV) plot, (c) Range time spectral width (RTW) plot. Corresponding temporal variations in OI 630.0 nm airglow measurements and the base of the F layer over dip equator are shown in (d) and (e)

Identification of a "Fossil" Plasma bubble

Coordinated VHF radar and 630 nm airglow observations from Gadanki (13.5°N, 79.2°E, dip lat 6.3°N) were carried out during April, 2006 and January-March, 2007. The field of view of the photometer was chosen to be the same as the radar beam width (~3°). The radar was operated in ionospheric mode wherein the beam was orthogonal to geomagnetic field lines over Gadanki. Optical measurements indicated that the ESF (Equitorial spread F) structure was depleted with respect to the background ionization during post-midnight hours. Radar measurements did not reveal predominant upward movement inside the same structure.

The movement of ambient ionization was deduced from Thumba ionograms, and these confirmed that the structure was in a decaying phase. Thus a unique evidence for a "fossil" bubble (remnants of a plasma bubble drifting across the radar field of view) was obtained using coordinated radar and optical observations (Fig. 4.6).

This work was done in collaboration with A. K. Patra, NARL, Gadanki and C. V. Devasia, SPL, VSSC, Thiruvananthapuram.

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

Sodium Airglow Observations during Meteor Showers

A portable narrow band (0.5 nm) sodium airglow photometer was developed and operated from Mt. Abu during moonless nights during November and December, 2006. The nocturnal variation of airglow during November month revealed the presence of extra-terrestrial source of sodium emission in addition to the terrestrial airglow. Preliminary results based on the phase propagation of the intensity variation at ~21:00 IST indicated presence of a wave with periodicity of ~2 days. Night-to-night variation in the intensity revealed an increase in background sodium airglow intensity by a factor of ~2 after ~2-3 days of the peak of Leonid shower. The intensity came back to the pre-shower level after another ~ 2 days. Some of the known mechanisms like the Chapman and Bates reactions do not explain the delay in the response in the sodium airglow. Interstingly, this feature was not observed after the Geminid meteor shower in December, 2006.

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

Coordinated Lidar and Airglow Observations in the Mesosphere

Coordinated sodium airglow and sodium lidar observations of mesosphere were carried out in the moonless nights during January-March, 2007. Height-time-intensity plots from sodium lidar revealed the altitudinal distribution of neutral sodium atoms with time in the mesosphere. On the other hand, sodium airglow intensity was proportional to sodium atoms and other sources. Comparison of the lidar and airglow data revealed good correlation only at certain intervals corresponding to a particular altitude region. This indicates that the excitation of sodium atoms leading to sodium airglow emission occurs at a particular altitude region in a time dependent manner.

This work was done in collaboration with Y. Bhavani Kumar, NARL, Gadanki.

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

Studies of Mesospheric Turbulence

Studies of mesospheric turbulence using simultaneous rocket-borne in-situ measurements of electron density from SHAR and MST radar at Gadanki, during July 21-28, 2004 were made with a RH-300 Mk II rocket, carrying Langmuir and ion probes (launched at 1142 hrs. on 23 July 2004). A RH-200 rocket was also launched at 1215 hrs to measure the winds (20-65 km) by radar tracking of copper chaff released at about 79 km. Strong mesospheric echoes were observed in the altitude range of 75-77 km. Langmuir probe detected a spectrum of electron density irregularities, with scale sizes in the range of 1 m to a few km, in the 67.5-71 km and 84-89 km altitude regions. MST radar also detected presence of a strong scattering layer in the 73.5 -77.5 km region from which radar echoes corresponding to 3 m irregularities were received.

(H. Chandra, H. S. S. Sinha, R. N. Misra, S. R. Das and Uma Kota)

Equatorial Electrojet studies

Data from simultaneous rocket-borne in-situ measurements of current density and electron density at Thumba (4 occasions under different geophysical conditions including one counter electrojet day) and Peru (1 occasion) were used to estimate the vertical profiles of conductivity, electron drift and electric field. The peak current density occurred at 106-107 km over Thumba and 109 km over Peru. The electron drift and electric field peaks occurred at 105-107 km over Thumba and 108-110 km over Peru. It was concluded that local electric field plays an important role in the spatial and temporal variability of the strength of electrojet.

Studies of the equatorial electrojet at two stations separated by 2000 km in South America have shown good correlation between the horizontal component of the geomagnetic fields (H) from two stations on day to day basis even after removing known sources. The correlation was attributed to planetary waves. Power spectrum of six months of data showed dominant period of 15 days at the two stations.

(R. G. Rastogi, H. Chandra and D. Chakrabarty)

VHF Scintillations Studies at Low Latitudes

Data for VHF scintillations at 244 MHz from a chain of low-latitude stations in India were studied. The onset times of scintillation at pairs of stations at similar latitude but different longitudes were used to estimate the eastward drift of the scintillation patches and their E-W extent. The maximum monthly mean occurrence for September 1991 was ~ 35% at Trivandrum and Tiruchendur (close to the dip equator). High values were found for Annamalainagar, Payyanur and Anantpur (50 %), (slightly north of the dip equator). These decreased further north to 30 % at Nuzvid, 20 % at Bombay (near anomaly crest region), 10 % at Agra and 8 % at Delhi.

(H. Chandra, G. D. Vyas and R. G. Rastogi)

Geomagnetic Storm Effects in Equatorial Ionization Anomaly and Equatorial Spread-F

Ionosonde data over Ahmedabad (23.1 °N, 72.4 °E) and at Kodaikanal (10.2 °N, 77.5 °E) were analyzed to study the geomagnetic storm effects during periods of high, medium and low solar activity. Data for more than 120 geomagnetic storms (covering different solar epochs 1989-1991, 1994-1996 and for the 1999-2001) of varying magnitude were analyzed. A total of about 60 storms (disturbance storm time index D_{st} < - 50 nT) of different strength occurred during the period 1999–2001. About 55% of the storms developed through a multi-step growth of the ring current during the main phase of the storms. About 35% magnetic storms were linked with magnetic clouds, and ~ 60% of intense and very intense magnetic cloud-associated magnetic storms developed through a multi-step increase of the ring current. About twenty geomagnetic storms of different strength, at least one from each class of storms (weak, medium and strong), were analyzed to study the interplanetary parameters of these storms, their effects on spread-F and on the strength of Equatorial Ionization Anamoly (EIA). The strength of anomaly was characterized by the echoes of f_oF_2. The temporal variations in the f_oF_2 over Ahmedabad and Kodaikanal together with incidence of spread F at two locations were studied for several geo-magnetic storm effects.

(Som Sharma, H. Chandra and H. S. S. Sinha)

Interactions of Solar Wind Electron and Galactic Cosmic Rays on Mars

The densities of positive ions and negative ions in the ionosphere of Mars were calculated at solar zenith angle 106° for altitudes 0 to 220 km, using a model which couples ion-neutral, electron-neutral, dissociation of positive and negative ions, electron detachment, ion-ion, ion-electron recombination processes through 117 chemical reactions. Of the 34 ions considered in the model, the chemistry of 17 major ions, such as O_2^+, NO^+, CO_2^+ etc. were studied in detail. At altitudes below 70 km, the electron density is found to be controlled mainly by hydrated ions and water clusters of NO_2^- and CO_3^-. The O_2^+ and NO^+ ions dominate above this altitude. The results suggest that the ionosphere of Mars contains F

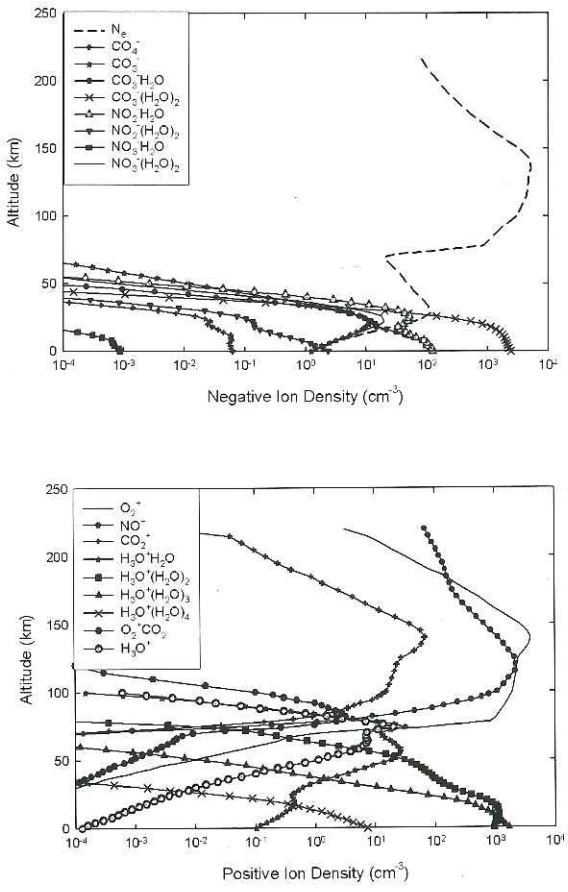


Fig. 4.7 : Computed profiles of positive and negative ion densities contributed by different species in the Martian ionosphere.

and D peaks at ~ 130 km and ~30 km due to the precipitation of solar wind electron and galactic cosmic rays respectively. The F peak is mainly produced by O_2^+ after heavy loss of CO_2^+ with atomic oxygen. The D peak occurs due to high efficiency of electron attachment to O_x molecules, resulting in a higher concentration of negative ions than electrons below 30 km. These results are shown in Fig. 4.7; the modeled contribution from different species to positive and negative ion densities are also indicated.

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

Radial distribution of Cometary Ion Density

A chemical model has been developed to study the chemistry of 46 ions, such as CH_5^+, SH^+, S^+ etc. in the coma of Comet Halley. The ionization sources included in the model are solar EUV photons, photoelectrons, and auroral electrons of solar wind origin. The production and loss rates and mass densities of these ions were calculated using the Analytical Yield Spectrum approach and coupled continuity equation controlled by steady state. In the vicinity of the ionosphere peak (~ 300 km), the most dominant ions are, H_3O^+ (40%), NH_4^+ (26%), $CH_3OH_2^+$ (20%), H_3S^+(5.3%), H_2CN^+(2.66%), H_2O^+ (1.66%). About 24 ions contributed 99% of the ion density in the coma of Comet Halley, while only less than 1% was contributed by other 22 ions. The calculated results are in good agreement with the Giotto ion mass spectrometer data.

This work was carried out in collaboration with Anil Bhardwaj, SPL, Trivandrum.

(S.A.Haider)

Anomalous Features in the Upper Ionosphere of Mars

About 800 electron density profiles observed by the radio science experiment onboard Mars Global Surveyor between 1998 and 2001 were analyzed. The peak electron density and height were found changing within a day though the solar conditions remained the same. This anomalous feature cannot be explained using photochemistry alone. Under the photochemical condition, changes in EUV flux should have a positive correlation between peak height and peak density. Other possible mechanisms like neutral atmosphere dynamics and solar wind interaction can explain some of these observed features. A transport model is being developed to study this problem, in which transport and interplanetary magnetic field are being included.

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

Bond Angles of Dissociating Molecular Ions

Under the Recoil Ion Momentum Spectroscopy Project,

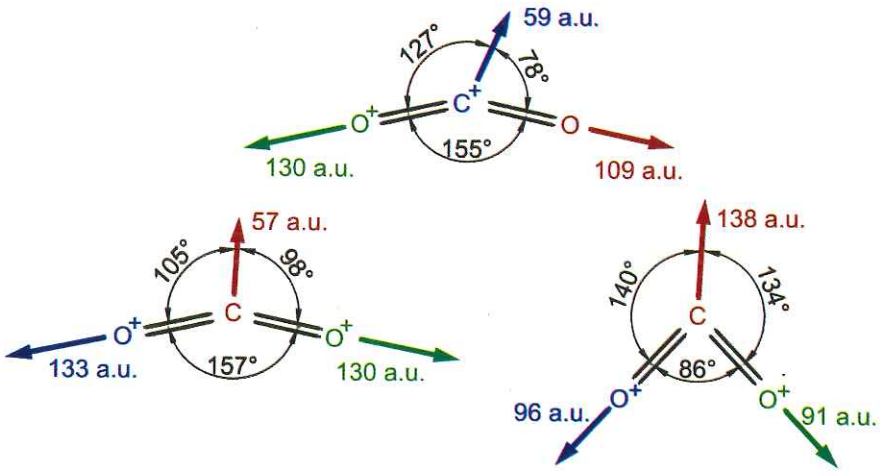


Fig. 4.8 : Bent dissociative states of CO_2^{2+} determined from the momentum distributions of ion and neutral fragments. The angles marked are the estimated bond angles, whereas the arrows indicate the most likely momenta of the fragments.

formation and fragmentation of polyatomic molecular ions were studied. A change in geometry of molecules undergoing dissociative ionisation was determined from momentum distributions of fragments. It was shown that the structure of CO_2 changed from linear to bent geometry when it was doubly ionised and dissociated. The O-C-O bond angles of the two states leading to dissociation were determined to be 156 and 88 degrees respectively, with an uncertainty of 8 degrees (Fig. 4.8). This work demonstrates the possibility of application of fragment spectroscopy for determining the bond angles of the parent molecular ion.

(B. Bapat and Vandana Sharma)

Bond formation during Dissociative Ionisation of Molecules

It was shown that CCl_4 changes from tetrahedral to quasiplanar when it loses two electrons under electron impact. It was shown that migration of one Cl atom occurs during this process and as a consequence the formation of Cl_2 was proposed. The change in symmetry was supported by computation of the structure by ab-initio methods.

(B. Bapat and Vandana Sharma)

Lifetime of Metastable Molecular Ions

Some of the bent states of CO_2^{2+} are metastable. The lifetime of the metastable state of CO_2^{2+} was determined by analysing the fragment velocities. The kinetic energy released in the reaction was also determined from the momentum of the fragments. These deductions support to the energy level and lifetime calculations of CO_2^{2+} carried out by collaborators at IIT, Kanpur. A similar study was done for the molecular ion SF_4^{2+}, but the lifetime could not be determined unambiguously.

(B. Bapat and Vandana Sharma)

Limits of Born-Oppenheimer Approximation

An experiment to investigate the breakdown of Born-Oppenheimer approximation in slow collisions between ions and molecules was carried out at the Inter University Accelerator Centre, Delhi. Due to the low collisional velocity, dissociative ionisation is not a function of the target molecule alone. For a diatomic target (CO) and an atomic ion projectile (O^{++}), the dissociation is expected to show three-body effects. Such decay of the target molecule projectile ion transient complex was investigated by time-of-flight spectrometry of the product ions.

(B. Bapat, Vandana Sharma and R. K. Kushawaha)

Dynamics of Plasma Plumes Produced by Laser Blow-off of LiF–C Thin Film

The time- and space-resolved emission profiles of Li I and Li II emission lines from the laser-blow-off plumes of a multilayered LiF–C thin film have been studied using spectroscopic techniques. The evolution features were analyzed in different ambient environments ranging from high vacuum to 3 mbar argon pressures and at various fluences of the ablating laser. During the evolution of the plume, a transition region between 4 and 6 mm was seen. In this region, the plume dynamics changed from free expansion to collisional regime, and experienced viscous force of the medium. The enhancement in neutral lines, as compared to ionic lines, was explained in terms of the yield difference in electron impact excitation and ionization processes. Substantial difference in the arrival time distribution of the plume species was observed for Li I and Li II lines at high ambient pressures. Three expansion models were invoked to explain the evolution of the plume in different ambient conditions. The laser fluence was found to control the ratio of ions and neutrals.

(R. K. Singh and Ajai Kumar, B. G. Patel and K. P. Subramanian)

Rotational Spectroscopic Studies of NO_2

Using Java HAWKS code of HITRAN database NO_2 molecule was identified for gas phase studies of rotational transitions in sub-millimeter frequency range. For the study of intensity, half width at half maximum for selected transitions, collisional, Doppler and natural broadening profiles were analyzed for laboratory conditions.

(A. Dubey, R. P. Singh, J. P. Pabari and N. M. Vadher)

Efficiency Enhancement of Optically Pumped FIR Laser

Efficiency of optically pumped far infrared (FIR) laser depends on various factors like degeneracy of FIR levels, frequency of pump radiation, transmission of FIR mirror, cavity loss at FIR

wavelength etc. In commercially available systems, almost all the above mentioned parameters have been optimized but much attention has not been paid towards extraction mechanism of FIR from output coupler arrangement. To collect the FIR power from array, horn antennas were used. To compute the available power, the entire structure was analyzed using High Frequency Structure Simulator (HFSS). Simulated results indicated significant improvement in the efficiency of optically pumped FIR laser. Apart from improved efficiency, highly intense and directive FIR output was observed in comparison with other available systems.

(A. Dubey)

Planetary Science and Exploration Programme

The academic activities of the Planetary Science and Exploration (PLANEX) programme during the year centered broadly around, 1) the design and development of the engineering model of the High Energy X-ray (HEX) payload for Chandrayaan-1 mission and, 2) research aimed towards understanding of early solar system processes, the formation and evolution of Moon and Mars.

High Energy X-ray Spectrometer for Chandrayaan-1 mission

The High Energy X-γ ray (HEX) spectrometer to be deployed in the Chandrayaan-1 mission is designed to study the nature of volatile transport on the moon using radon as a tracer through measurement of 46.5 keV line from ^{210}Pb, a decay product of ^{222}Rn. In addition, U and Th contents and dominant lithology of lunar surface will be inferred from the study of emissions from low energy (30-270 keV) natural γ rays from the lunar surface due to radioactive decay of the ^{238}U and ^{232}Th. The desired energy resolution of the spectrometer is about 10% at 60 keV.

Pixilated Cadmium Zinc Telluride (CZT) detector arrays will be used in the HEX experiment. The geometric detector area of 144 cm^2 is realized by cascading 9 CZT arrays, each 4 cm×4 cm×0.5 cm, and composed of 256 pixels. Signals generated by the photons incident on any of the 2304 individual pixels are read out using a chain of XAIM 3.3 ASICs, that allows identification of the triggered pixel and the energy of incident photon. The ASIC gives current output whose magnitude is proportional to the energy of the incident photon. The Front-End Electronics (FEE) handles the analog ASIC outputs for energy, trigger and pixel address information. Energy information is digitized by a 10-bit ADC. Energy, position and other informations are formatted by the processing electronics and transmitted to ground station through telemetry. The detector package and front end electronics is being designed and developed at PRL, while the anti-coincidence, the data acquisition and the processing systems are being developed at SAID, ISAC.

The mechanical and electrical design of HEX payload has been finalized. Fabrication will be in three stages, viz

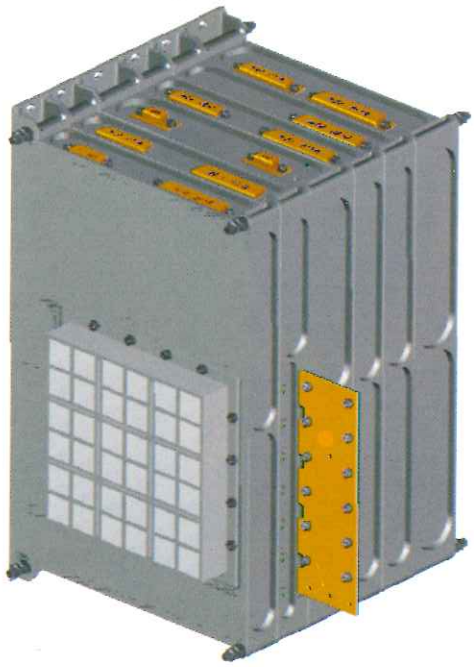


Fig. 5.1 : HEX detector package made up of six trays consisting of detector, front - end electronics, anticoincidence and power systems. Extra projection (Cu-coated) seen on the right hand side provides route for effective transfer of heat from the detector tray to a radiator plate for maintaining optimum temperature.

engineering model, qualification model and the flight model. Engineering model uses electrical and mechanical interface similar to other models except for the use of commercial components and Al instead of Mg-alloy for payload housing of six trays (Fig. 5.1). Fabrication and testing of all the trays for the engineering model have been completed by interfacing the HEX detector package with processing electronics developed by SAID, ISAC. The spectra observed from these end to end tests are shown in (Fig. 5.2). The primary specifications: energy resolution (10% at 60 keV) and detection threshold ($\leq$30 keV) are adequately met. Evaluation of different signal parameters with the interfaced circuits is being carried out and minor modifications are being implemented to improve the system performance and electronics noise in the qualification model.

(Y.B. Acharya, S. Vadawale, M. Shanmugam, D. V. Subhedar, Harshadkumar L. Patel, S. U. Sharma, S. Purohit, V. Shah, S. L. Kayasth, V. J. Vaibhavi and J. N. Goswami)

Iron and titanium concentrations of the central peaks of lunar craters

Central peaks of lunar craters are important units on the lunar surface since they expose rocks from depth. Using five band UV-VIS data of Clementine mission, an analytical approach to derive average iron and titanium concentrations of the central peaks of lunar craters were developed. This approach, takes into consideration the topography and other photometric constraints, and has led to the following observations: a) Compositional heterogeneity exists both at lateral and depth scales across the lunar crust; b) central peaks of certain craters have exposed deep seated basaltic/ gabbroic rocks as indicated by their enhanced iron and titanium concentrations. This suggests that they are of mantle origin as opposed to primary origin. The study also indicates that simultaneous assessment of chemical concentration along with lithology of the central peaks provides a better understanding of the composition, genesis and extent of the subsurface rock types. We have identified the Scaliger, Bullialdus, Biirkeland and Campanus craters, for further analysis using the hyperspectral and topographic data from Chandrayaan – 1 mission.

(Neeraj Srivastava)

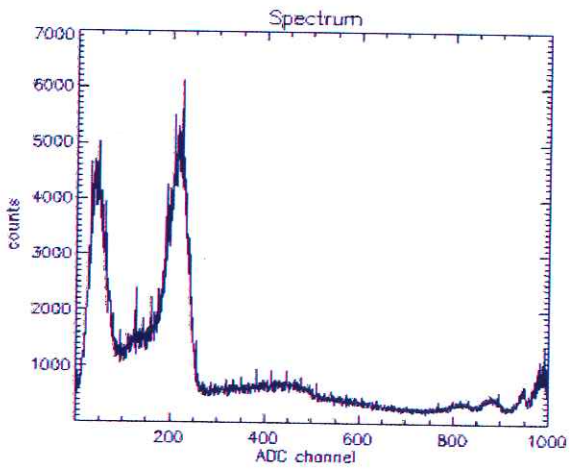


Fig. 5.2 : Measured spectra during end to end tests of Engineering model of HEX detector package interfaced with processing electronics using ^{133}Ba (31 and 81 keV) source. A detection threshold of 30 keV is clearly achieved. Energy resolution at 80 keV is better than 10% at room temperature.

Radial mineralogical trends in fresh impact craters on Moon

Impact cratering systematically excavates material from the sub-surface and deposits it in a sequential manner as ejecta around the crater. The nature of compositional variation of the ejecta provides important information about the pre-impact stratigraphy of the sub-surface. Floors of Lunar craters of various sizes were sampled to assertain any change in mineralogy with depth. Quantitative estimates of mineral abundances have been made using Clementine UV-VIS datasets and available algorithms (suitably modified). Many fresh craters on the floors of pre-existing craters, as well as in areas around target crater exhibit radial trends in mineral maps generated in this study. Such a pattern on crater floor can be generated by excavation of a crystallized melt sheet while those on areas away from target crater are most likely due to re-distribution of material by excavation of relatively undisturbed ejecta pile.

(D. Dhingra)

Thermoluminescence studies of single chondrules

Chondrules are millimeter sized near spherical objects that comprise upto 80% of the volume of chondritic meteorites. These are considered to be a product of high temperature processes in the solar nebula. It has been previously shown that the thermoluminescence sensitivity of bulk material is an indicator of the degree of thermal metamorphism in type 3 unequilibriated ordinary chondrites (UOC). Measurements of thermolumine scence sensitivity and chemical characterization of individual chondrules from the type 3.8 Dhajala meteorite were made to investigate the cause leading to the observed variations in the measured chondrule TL sensitivity. All the chondrules of Dhajala meteorite have TL sensitivities lower than the bulk value. Major element concentrations (Si, Al, Ca, Ti, Fe etc.) of mesostasis of some of the chondrules were determined by EPMA. However, in contrast to earlier results, we find no dependence of TL sensitivity on the abundance and composition of mesostasis. We propose that individual chondrules from UOC of low petrologic grades having TL sensitivities much higher than the bulk chondrite, may have experienced thermal metamorphism in a nebular or parent body environment prior to being incorporated into the parent meteorite.

(D. Banerjee, V. Mahalingam and D. K. Panda)

Cosmic ray induced dose-rate within a Martian soil profile

We have considered the Martian atmosphere and soil profile and used the Geometry and Tracking (GEANT) code library to model electromagnetic and hadronic processes occurring on Martian surface due to interactions of galactic cosmic rays. The results of our simulation show that at the Martian surface the total cosmic-ray induced dose-rate is ~51 mGy/a, assuming a 2π (integral) GCR flux of 1.5 protons cm^{-2} s^{-1}. Although this value matches the dose rate obtained by others using the HZETRN code, the dose-depth dependence obtained by us is different from that obtained in the earlier calculations. The cosmic-ray dose-rate in the Martian soil profile decreases to 50% of the surface value at a depth of ~12 cm, to 30% at ~30 cm and to 1% at ~2.8 m. The surface dose-rate is about 100 times higher compared to the environmental dose-rate, ~0.6 mGy/a, calculated using K, Th, and U concentrations of 0.1%, 2 ppm and 0.5 ppm respectively, for Martian soil. Thus, for deeply buried (> 3 m), sediments on Mars, the environmental dose-rate will be higher than cosmic-ray dose-rates. This will be an important input for initial dating of Martian Surface using Luminescence.

(D. Banerjee)

Recently fallen Indian meteorites

Two meteorites, Kaprada and Jodia, fell in Gujarat in August 2004 and June 2006 respectively. Oxygen isotope measurements suggest that both are ordinary chondrites of class L. Noble gas and nuclear track analysis enabled delineatation of the cosmic ray exposure history and thermal metamorphic class of these chondrites. Kaprada has a cosmic ray exposure age of 11.4 Ma and low amount of trapped heavy noble gases suggesting it to be of class L5/6. Low track density and low shielding parameter $(^{22}Ne/^{21}Ne)_c$ suggest that Jodia is a large meteoroid (> 50 cm radius). An exposure age of 26 Ma can be derived, assuming average shielding for the analyzed sample. A nominal K-Ar age of 4.5 Ga suggest good

Fig. 5.3 : Photographs of the three instruments installed at the PLANEX National Facility along with a backscatterd electron image of a meteorite section taken with the EPMA where several chondrules (the objects with round shape) can be seen (scale bar = 1mm).

gas retention. Low amounts of trapped noble gases suggest that Jodia belongs to class L5/6.

This work was done in collaboration with Dr. V. K. Rai, Univ. of California at San Diego, USA.

(R.R. Mahajan , S.V.S. Murty, A.D. Shukla, N. Bhandari, and N. Sinha)

Planetary and Geosciences

Records of now-extinct nuclide ^{60}Fe in the early solar system

The presence of the now-extinct, short-lived nuclide ^{60}Fe (half-life = 1.5 Ma) in the early solar system has been established from study of Fe-Ni isotope systemetics in meteorite samples in recent years. However, the reported solar system initial ^{60}Fe/^{56}Fe ratio varies over a wide range, ~10^{-7} to a few times 10^{-6}. ^{60}Fe is a unique product of stellar nucleosynthesis and a robust value for solar system initial ^{60}Fe/^{56}Fe is essential to infer its plausible stellar source and to estimate the contribution from such a source to the inventory of the various short-lived nuclides such as ^{26}Al (half-life = 0.73 Ma) present in the early solar system. No systematic attempts have been made as yet to look for records of both ^{60}Fe and ^{26}Al in individual early solar system objects. We have initiated such a study in a set of chondrules from the unequilibrated ordinary chondrite Semarkona that were analyzed for ^{26}Al by us.

The Fe-Ni isotopic measurements were carried out using a Cameca ims-4f ion microprobe at a mass resolution (M/ Δ M) of ~4000 sufficient to resolve the major interference in the masses of interest. The low concentration of Ni required long counting times and individual analysis typically lasted more than two hours. This required precautions to ensure instrument stability (Fig. 6.1). Preliminary results in a semarkona chondrule yielded an initial ^{60}Fe/^{56}Fe value of $(2.31\pm1.8)\times10^{-6}$ (2σ error). This chondrule has a very well defined initial ^{26}Al/^{27}Al value of $(5.4\pm0.5)\times10^{-6}$ indicating its formation at least 2 Ma after Ca-Al-rich Inclusions (CAIs), the first objects to form in the solar system. This would suggest that the ^{60}Fe/^{56}Fe value measured by us needs to be multiplied by at least a factor of two to obtain the true initial solar system ratio. An initial ^{60}Fe/^{56}Fe>10^{-6} will have important implications both in identifying the stellar source of ^{60}Fe as well as its possible role as an effective heat source in the early solar system. Further work is in progress to analyze more chondrules and improve the precision of the inferred initial ratio.

(R. Mishra and J. N. Goswami)

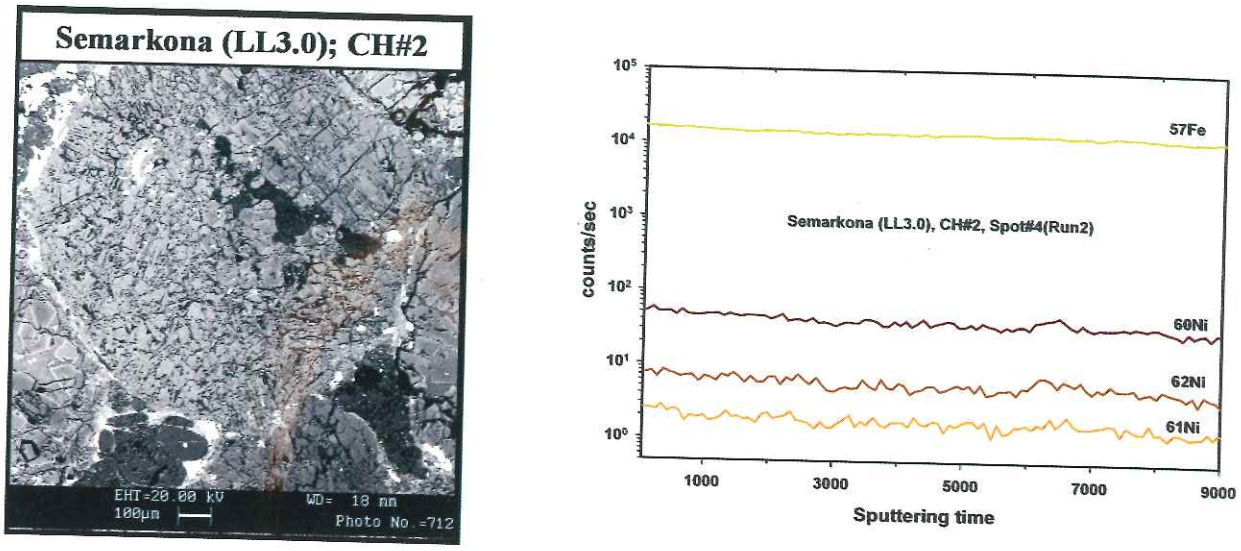


Fig. 6.1. Measured count rates for Fe and Ni ions in a Semarkona chondrule (#2, circular object in left photograph) during a single run.

Lifetime of the solar nebula

The duration of formation of the two early solar system objects, the CAIs and the chondrules, that are considered to be products of high temperature nebular processes, effectively defines the lifetime of the active solar nebula. Most of the CAIs host radiogenic isotopic anomalies from in-situ decay of short-lived now extinct nuclides and ^{26}Al records in them suggest their formation over a time scale of a few times 10^5 years. Based on work done by us and those reported by other groups, there is a general consensus that formation of chondrules began about a million years after the formation of the CAIs. However, (based on study of ^{26}Al records) the inferred duration of chondrule formation varies from <1Ma to 3Ma. Our study of chondrules from nine unequilibrated ordinary chondrites (UOCs) belonging to the L and LL groups and representing various petrologic types, show that the major episode of chondrule formation lasted <1.5 Ma. The longer duration of formation, inferred in earlier studies, appears to be an artifact of thermal metamorphism affecting some of the chondrules of low petrologic type. Thus energetic events in the solar nebula capable of producing CAIs and chondrules must have lasted for about three million years defining the lifetime of the active solar nebula. Lifetime of disks around new born stars based on astronomical observations is compatible with this value.

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

Insoluble Organic Matter in Chondrules

Chondrules are one of the earliest formed solids in the solar system and occupy upto 80% by volume of chondrites. A comprehensive investigation of nitrogen in individual chondrules of the three main chondrite classes, Ordinary Chondrites (OC), Carbonaceous chondrites (CC) and Enstatite

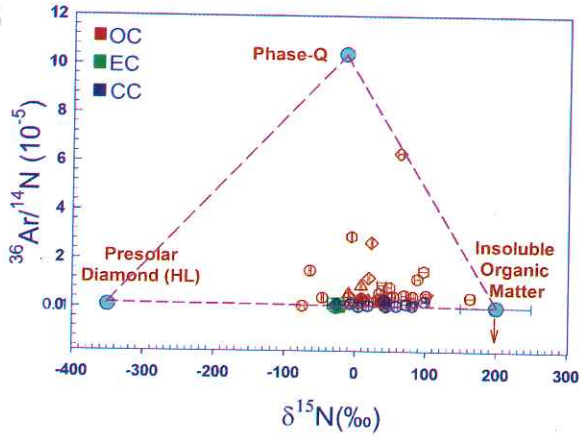


Fig. 6.2 : Nitrogen data for individual chondrules from ordinary, carbonaceous and enstatite chondrites are displayed in a plot of $\delta^{15}N$ vs. (^{36}Ar/^{14}N). At least three components (Q, HL and IOM) are needed to explain the N data of chondrules. Also, the clustering of EC data in a narrow region of the plot emphasises that N components are well homegenized in the precursors of EC.

chondrites (EC) was undertaken. Isotopic composition of nitrogen suggested that i) chondrules from OC and CC had precursors that are different than their respective parent chondrites, while those from EC have similar precursors; ii) the precursors of OC and CC chondrules are different than those of EC chondrules. A plot of $\delta^{15}N$ vs. the elemental ratio $^{36}Ar/^{14}N$ (Fig. 6.2) suggests common precursors, for EC chondrules while the data of OC and CC show a large spread. The chondrule nitrogen data can not be explained by a two component mixture of Q and HL components. A third component with $\delta^{15}N$ > 100‰ and with negligible ^{36}Ar is required. Insoluble organic matter (IOM) fits the bill perfectly, for the third component. This observation suggests that IOM could be prevalent in the region of the early solar nebula where OC and CC chondrules formed.

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

Primitive meteorites from Deserts

Two primitive meteorites viz., NWA 1500 (an achondrite) and SaU 290 (a metal rich CH chondrite), collected from hot deserts were investigated for nitrogen and noble gases to learn about the early solar system processes.

Trapped noble gas amounts [^{36}Ar = 6.1x10^{-8} ccSTP/g, $^{36}Ar/^{132}Xe$ = 249 and $^{84}Kr/^{132}Xe$ = 1.26] were very low but the isotopic ratios $^{40}Ar/^{36}Ar$ = 12.2 and $^{129}Xe/^{132}Xe$ = 1.13 were significantly above typical ureilites. The N content was 3.6 ppm with $\delta^{15}N$ of 10.8‰. Nitrogen in bulk monomict ureilites range between 6 to 55 ppm ($\delta^{15}N$ (‰) -2 to –70), with different polymorphs of C being the major carrier phases of N. The elemental ratios $^{36}Ar/^{132}Xe$ and $^{84}Kr/^{132}Xe$ of NWA 1500 do not match with ureilites, but are closer to brachinites. Comparison of NWA 1500 data with those of winonaites and brachinites, for oxygen isotopes, noble gas elemental and $^{129}Xe/^{132}Xe$ ratios confirm it to be brachinite.

Based on petrology, chemistry and O-isotopes SaU 290 was classified as CH3. Light noble gases (He, Ne) in SaU 290 are dominated by solar component, while trapped Ar, Kr and Xe are similar to E-chondritic component. CH chondrites are recognised by their characteristic heavy $\delta^{15}N$ value of ~1000 ‰ and total N (117 ppm) with $\delta^{15}N$ (914 ‰) present in SaU 290 falls in the range of other CH meteorites. The gas release at different temperature clearly shows that the principal carriers of N and heavy noble gases are different. Based on combustion temperature and C/N ratio, at least four N components have been identified in CH chondrites, with two low temperature components [950 ‰ (250-350 °C), 500 ‰ (400-525 °C)] and two high temperature components with > 1000 ‰. The SaU 290 data clearly suggests the presence of a N component with $\delta^{15}N$ < 400 ‰, hosted in non carbonaceous phase and having high release temperature (> 1200 °C).

This is work was done in collaboration with R. Bartoschewitz from Germany.

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

Electron Paramagnetic studies on Feldspars

Feldspars (alkali alumino silicates $Na/KAlSi_3O_8$) are ubiquitous minerals in the Earth's crust. An understanding of the physical properties of unpaired electrons (both localized and itinerant if any, (e.g. hopping O^-) in the matrix, is needed to obtain a greater insight in to luminescence process and mechanisms of its thermal/athermal decay. Electron Paramagnetic Resonance (EPR) of six feldspar comprised lines at g = 4.3 and 2.54 in addition to sample dependent signals. The line position of signal with g ~ 2.54 shifted with radiation dose i.e. lower g-values with higher radiation dose. Such a dependence of ESR line position on radiation dose is rare (observed only once previously), and arises due to the interaction of itinerant electrons with static paramagnetic centers. We suggest that,

1) The line at g = 2.54 is due to interaction of mobile oxygen hole centers with static Fe^{2+}/Fe^{3+},
2) The dose dependence of line position is the manifestation of increasing number of oxygen hole centers with dose.
3) Given the high precision of the g value measurements in modern ESR systems, we conjecture the use of the dose dependence of g = 2.54 line for radiation dosimetry and geochronology.

This work was done in collaboration with BARC scientists led by Dr. K.P.N. Mishra.

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

Components of Optically Stimulated Luminescence weakly luminescent samples

Extraction of the components of OSL decay in weakly

luminescent samples with a poor signal to noise ratio (SNR), was examined. For samples with poor SNR, it is difficult to compute a growth curve using the conventional Single Aliquot Regeneration Technique. The component specific paleodose (CSD) estimation for such samples was examined using *Lavenberg-Marquardt* algorithm on synthetic profiles that were generated using a known OSL profile with Poisson noise super imposed. This permitted controlled test on predetermined SNR values. The algorithm critically depended on SNR and it was suggested that such samples could still be handled by reducing the total parameters. This was achieved by estimating the decay parameters from the OSL decay of the same sample following a high dose. These parameters were used as constants in LM protocol and these worked well in providing reliable intensity estimations with significantly improved precision.

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

Isolation of quartz signal from feldspar contaminated sample

On account of their poor bleachability and the presence of longterm fading, feldspar contaminated quartz grains can at times provide erroneous age estimation. In a laboratory simulation study, varying proportion of feldspar were mixed in quartz and then their OSL was recorded. Using the component specific technique it was possible to isolate the fast components of quartz and feldspar crystals, based on their distinct decay rates. For plagioclase feldspar, the decay rate was about ~0.8 sec^{-1}, while for quartz it was around ~2 sec^{-1}. Using the decay rates it is possible to resolve the fast component of quartz sample containing feldspar as contaminant up to 30% by intensity.

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

Climatic and tectonic settings during the Last Glacial Stage in Higher Central Himalaya.

Climatic instability in the areas proximal to valley glaciers is manifested by the spatial distribution of moraines, glacial lakes and the gravel plain. Of the available archives, lake sediments provide a near-continuous record of climatic change on account of their higher preservation potential. In temperate glaciers such as in the Himalaya, the sediment flux into such lakes is associated with climatically modulated glacial fluctuations. Annual cycles result from deposition of silt during summer, and fine clay and organic debris during the winters. These were used for high-resolution palaeo-climate reconstruction.

In the Higher Central Himalaya, a 13 m thick relict lake succession comprising varve and rythemites was analyzed for multiple climate-proxies. This lake succession at Goting (30° 49' N and 79° 49' E) lies immediate south of the Tibetan Plateau. Analysis of the sedimentary structures, mineral magnetism, geochemical analyis, and optically stimulated luminescence (OSL) chronology of sediments suggested a fluctuating hydrological regime that was modulated through glacial meltwater discharge during >25 ka to <11 ka. Four inferred climatic excursions were: i) a cool and dry phase between 25 - 21.5 ka, ii) a warmer phase between 21.5 -16.5 ka, iii) a phase of cooling between 16.5 and 14.5 ka, and iv) a gradual climatic amelioration culminating in deposition of outwash gravels at ~11 ka.

High frequency fluctuations in the mineral magnetic and the major elemental data with a periodicity of ~200 yrs suggests of a correlation with the solar activity. Correspondence between the present data with that of the Greenland Ice core data and the Northern Atlantic marine record suggests that climate oscillations in the Higher Central Himalaya were linked to the climatic instability in the northern latitude.

This work was done in collaboration with N. Basavaiah (IIG), M. Jain (Riso National Laboratory, Denmark), R.K. Pant (Wadia Insititute), N. K. Saini (Wadia Institute).

(N. Juyal, R. Bhushan, M.G. Yadava and A.K. Singhvi)

Carbonaceous Aerosols in the MABL of Bay of Bengal

Carbonaceous aerosols comprising elemental carbon and organic compounds are a significant component of suspended particulate matter in the atmosphere. Measurement of their concentration in the marine atmospheric boundary layer (MABL) enables better constraints on the radiative forcing over oceanic regions. In this context, the total suspended particulates (TSP), Elemental carbon (EC) and Organic carbon (OC), were measured in the MABL of Bay of Bengal (area: 6 to 20° N; 80 to 92° E) during 19th March to 12th April 2006. The

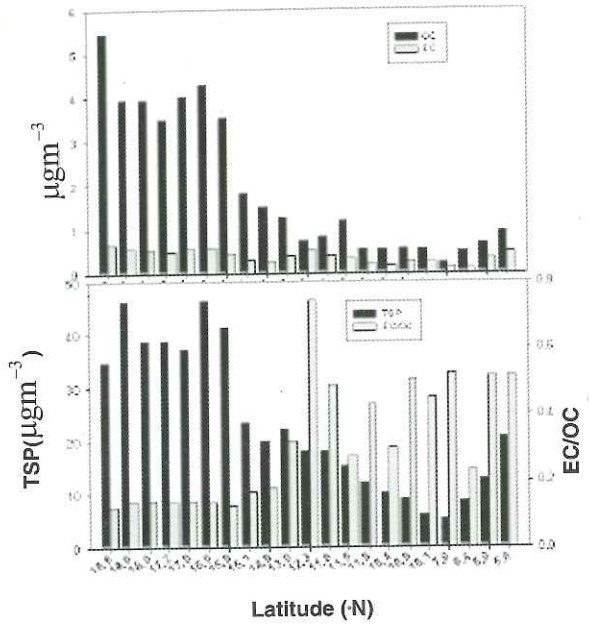


Fig. 6.3 : Latitudinal variation of TSP and carbonaceous components in MABL of Bay of Bengal

TSP ranged from 5.2 to 46.6 µgm^{-3}, (Av = 22.5 µgm^{-3}). EC varied from 0.12 to 0.66 µgm^{-3} and was about 2 % of the TSP. The EC levels show a distinct spatial spread with higher values over the northern Bay, decreasing southwards (Fig. 6.3). The five-day back trajectories of air masses suggest that these originate within the marine environment and the EC concentrations (Av =0.30 µgm^{-3}) represent the background levels over the south-central Bay. The OC ranged from 0.26 to 5.5 µgm^{-3} and had a significant linear trend (r=0.76, n=22, p<0.001) with EC, suggesting their transport by similar process. The EC/OC ratio varied between 0.12 and 0.52, relatively higher values occurring in the central and southern Bay compared to northern regions. The higher EC/OC ratio in southern Bay of Bengal is attributed to steep north-south decreasing gradient in OC levels.

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

Chemical characterization of mineral aerosols in the MABL of Arabian Sea

Mineral dust contributes a significant fraction of the globally produced aerosols and influences the biogeochemical cycles of several constituents in the lower troposphere and at the air-sea interface via dry-deposition. Chemical characterization of mineral dust in the marine atmospheric boundary layer (MABL) is, thus, essential. With this perspective, a cruise was undertaken in the Arabian Sea during April 18 – May 10, 2006 and bulk-aerosols were sampled in the area between 9° to 21°N latitude and 75° to 58°E longitude.

Total suspended particulates (TSP) exhibit large spatial variation with maximum value of 46.9 µgm^{-3} (on May 8 at 21 °N, 66 °E) and minimum of 8.2 µgm^{-3} (on April 30 at 14 °N, 66 °E). Relatively high TSP occurs in the northern Arabian Sea compared to that in the south. The mineral dust (normalized to TSP) shows an inverse trend from north to south. This is supported by seven-day back trajectory analysis of air masses, that originate from the coastal region of Oman (source of dust). The back trajectories in the latitudinal belt (12 - 20 °N) originate within the MABL.

The concentrations of Al, Fe, Ca, and Mg also varied significantly. Statistically significant linear relationship among Al, Fe, Ca, and Mg was seen over space and time (Fig. 6.4). The ratios: Fe/Al (0.56), Ca/Al (1.21), Mg/Al (0.35) are significantly different than those in upper continental crust (0.44, 0.35, and 0.17 respectively). Thus the mineral aerosols over the Arabian Sea have a characteristic chemical signature.

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

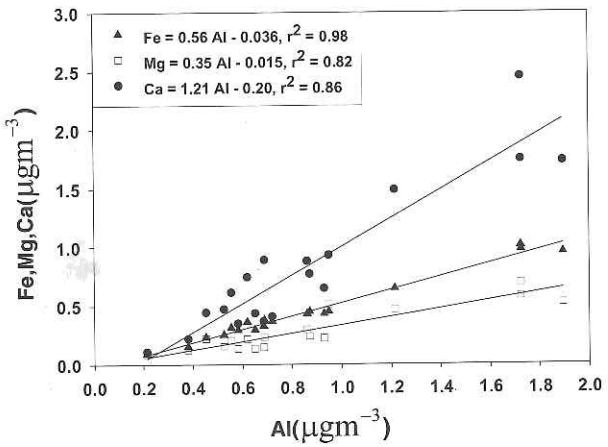


Fig. 6.4 : Relationship among crustal elements.

Carbonaceous Aerosols over Urban Atmosphere and High Altitude Site in North India

Daily samples of bulk-aerosols, collected over a 30 day period during winter season (Dec. 2004) from a high altitude site (Manora Peak, 1950m asl, 29° 24' N, 79° 28' E) and from an urban location (Allahabad, 123m asl, 25° 24' N, 81° 52' E) in North India, were analyzed for elemental carbon (EC) and organic carbon (OC) using thermal-optical reflectance (TOR) protocol. The total suspended particulates (TSP) over Allahabad ranged from 180 to 530 g m^{-3} (Av. 300 g m^{-3}) and that at Manora Peak as 13.7- 42.7 g m^{-3} (Av. 28.2 g m^{-3}). OC abundance varied from 26.8 to 76.5 g m^{-3} (Av. 49 g m^{-3}). EC varied from 3.1 to10.6 g m^{-3} (Av. 6.2 g m^{-3}; 2.1 % of TSP) over Allahabad and those at high altitude site were 3.1-7.1 g m^{-3} (Av. 5.1 g m^{-3}; 18.1 % of TSP) and 0.3-1.4 g m^{-3} (Av. 0.9 g m^{-3}; 3.2 % of TSP) respectively.

The contribution of total carbonaceous aerosols (TCA =1.6*OC +EC) to TSP is nearly identical at these two sites and account for nearly 30 % of aerosol mass. A significant linear relationship (R^2=0.81) between OC and TSP at Manora Peak was observed. The OC/EC ratios at the two sites (Manora Peak, range: 3.9-13.4 (Av. 5.1) and Allahabad, range: 5.7-11.4 (Av.8.1)) are high compared to the reported values of 2.0-3.0 for urban region in Europe. Furthermore, a significant linear correlation between EC and OC (R^2=0.67) at Manora Peak suggest their common emission source, whereas large scatter in the EC-OC data from Allahabad indicates dominance of secondary organic carbon, contributing as much as 50 % (Av. 28 %) of OC.

The long-term (Feb 2005 to June 2006) sampling of aerosols from Manora Peak reveals large temporal variability in the abundances of TSP, OC and EC (Fig. 6.5); with higher abundances occurring during March to June. However, these samples are characterized by low (~16 %) contribution of TCA to TSP, suggesting the dominant role of mineral dust during summer months.

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

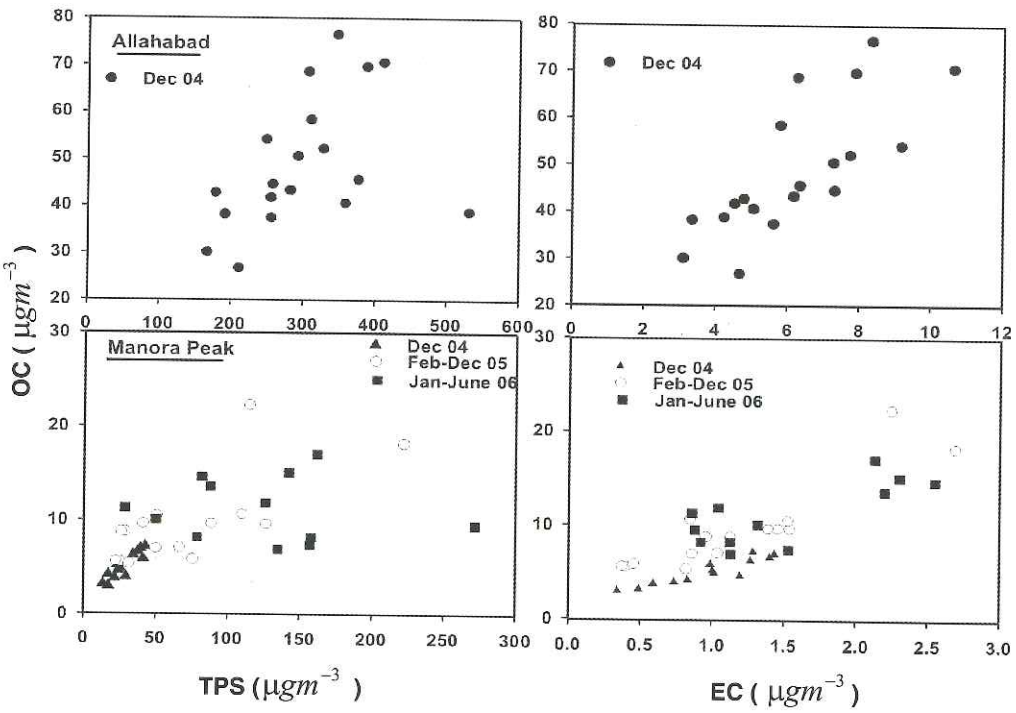


Fig. 6.5 : Scatter plot among TSP, EC and OC for aerosol samples collected from urban location (Allahabad) and high-altitude site (Manora Peck).

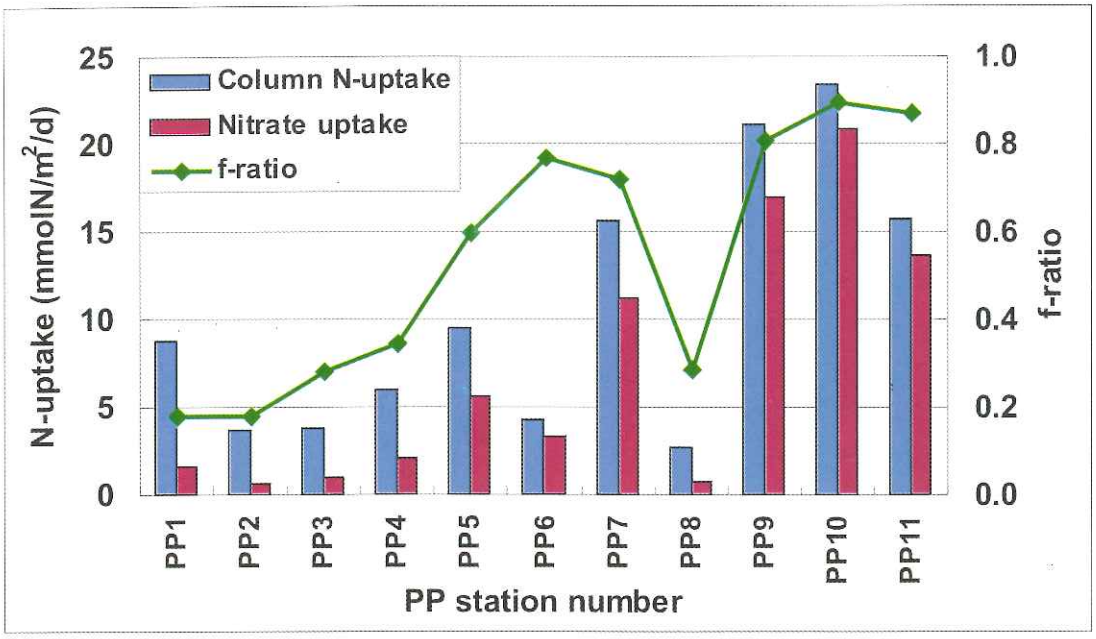


Fig. 6.6 : Station-wise column-integrated total N-uptake, nitrate uptake and f-ratio for eastern Arabian Sea during Feb-March 2004

High New Productivity in north eastern Arabian Sea during a Noctiluca scintillans bloom during winter

^{15}N serves as an important tool to estimate new productivity that is equal to the export of carbon out of the surface ocean. We measured the nitrate, ammonium and urea uptake rates and f-ratios, using the ^{15}N tracer technique, in the eastern Arabian Sea during a *Noctiluca scintillans* bloom in the winter-2004. Sampling was done at 11 different stations on board *FORV* Sagar Sampada (SS 222) during the winter monsoon (20th Feb to 11th March, 2004) in the northeastern Arabian Sea.

Total N-uptake rate was carried out integrated over the water column from the surface upto 1% light level (euphotic depth), ranged from 2.7 to 23.4 mmol N m^{-2} d^{-1}, with a mean of 10.4 (±7.4) mmol N m^{-2} d^{-1}. In the southern stations (i.e., 10°N to 14ºN) column-integrated total N-uptake varied from 3.6 to 8.8mmol N/m^2/d, being the highest at the southern-most station. Nitrate uptake was less, 0.6 to 2.1 mmolN/m^2/d. f-ratio increased progressively towards the north; from 0.18 to 0.34.

During the *Noctiluca* bloom, N-uptake and f-ratio increases significantly; mean N-uptake and f-ratio in the northeastern Arabian Sea, are 20.1 (± 4) mmolN m^{-2} d^{-1} and 0.86 (±0.06) respectively. Our column N-uptake values are comparable with the values reported (23.2 mmol N $m^{-2}d^{-1}$ for the bloom station), but our f-ratios are significantly higher. Higher f-ratios suggest efficient utilization of available nitrate in the water column during the *Noctiluca Scintillans* bloom.

Our study indicates the presence of two entirely different biogeochemical provinces that can broadly be divided as: T1 (south of 20ºN) and T2 (20ºN to 25ºN). Province T1 is supported by the recycled nutrients and characterized by low column N-uptake (and low f-ratio). Though low, the f-ratio increases progressively towards north. Province T2 is a highly productive zone, with very high N-uptake and significantly high f-ratio. The column integrated total production (x) and new production (y), show a significant correlation: for non-bloom stations: $y = (0.44 \pm 0.22)\,x - (0.31 \pm 1.34)$; (coefficient of determination, $r^2 = 0.45$) and for bloom stations, $y = (1.0 \pm 0.20)\,x - (4.1 \pm 4.04)$; ($r^2 = 0.93$). The slope of the regression is the maximum possible value of the f-ratio. High f-ratios during

a bloom indicate a high dependence of total production on the new production whereas during the absence of bloom, regenerated production contributes significantly to the total production.

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

Is the Arabian Sea getting more productive?

Ocean colour data from the Indian Satellite Oceansat-I enabled large areas of the ocean to be monitored for years to detect changes in chlorophyll pigments and hence productivity. Using such data for the western Arabian Sea, earlier workers concluded that during the recent past marine productivity has increased. They attributed this to global warming and the consequent strengthening of the monsoon. Paleoclimate data suggest that the summer and winter monsoons behave oppositely, and an increase in marine productivity due to a stronger summer monsoon should be concurrent with a weaker winter monsoon and hence a reduced winter productivity in the north-eastern Arabian Sea. A detailed analysis of SeaWiFs data from the eastern Arabian Sea provide no evidence to show that global warming has significantly changed the marine productivity. Analysis of 8 years record of satellite ocean colour data over the north-eastern Arabian Sea suggests that chlorophyll concentration has not changed significantly in this region, and is thrice that in the south-eastern part. The reported trend in Chl-a in the western Arabian Sea is not observed in the eastern Arabian Sea and hence we conclude that the increase in Chlorophyll in the western Arabian Sea not be entirely attributed to global warming.

(R. Ramesh and Satya Prakash)

Provenance of sediments in the Bay of Bengal

The sediment deposition in the Bay of Bengal is significantly influenced by the seven rivers draining into it with major contributor being the Ganga and Brahmaputra river system. To understand these processes, chemical and isotopic measurements were carried out in surface sediments from the Bay of Bengal. The sediments derived from the various river sources and distributed in the Bay of Bengal should mimic the signatures of their provenance. Sr and Nd isotopic composition of the silicate fraction of the surface sediments show strong influence of G-B rivers in the northern Bay of Bengal with high $^{87}Sr / ^{86}Sr$ (0.725-0.735) and low ε_{Nd} (-18 to -12).

The samples from the western Bay of Bengal show mixed signature of Sr and Nd isotopes derived mainly from the rivers draining in the western continental margin of India. The samples from the Andaman Sea have least radiogenic Sr and more radiogenic ε_{Nd}, supposed to be influenced by sediments from the Irrawady river.

(R. Bhushen, S. K.Singh)

Longer-term periodicities in the proxy record of the Indian monsoon rainfall

Fast Fourier Transform (FFT) and the Maximum Likelihood Analyses (MLA) of time series stable carbon ($\delta^{13}C$) and oxygen isotopes ($\delta^{18}O$) of the last 331 years of an annually laminated speleothem reveal significant power in several periods that have a likely solar origin e.g. 132, 21, 18, and 2.4 years. These cycles are non-stationary in nature. Wavelet analysis (Fig. 6.7) suggests that the ~21-year period is strong during 1850 to 1920 A.D. Between 1780 and 1920 A.D., low rainfall intervals

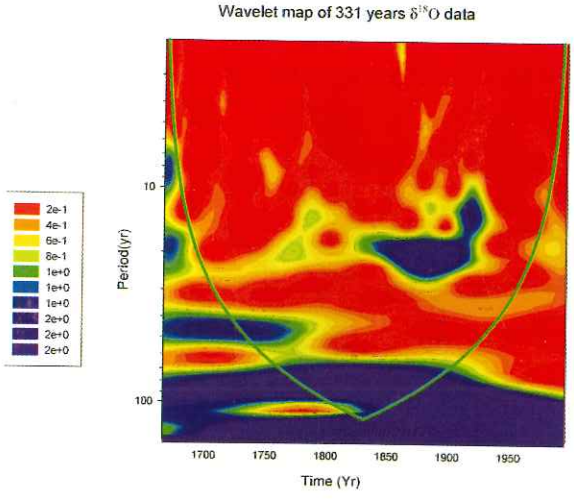


Fig. 6.7 : Wavelet map of the ^{18}O time series. The left side shows Fourier period (in yr) and the bottom shows time (yr). The line contours are plotted to show the boundaries of the colour levels, shown in the box, indicating power that is significant at 90% level. Area between thick dark line and the time axis is the "cone of influence", where edge effects are important.

are concurrent with low solar activity. However, this behaviour breaks down for the older periods. In the ^{13}C periodogram, additional significant periods appear viz. ~59, ~8, ~ 6.5 and ~3 years: these could have originated from solar variations and/or changes in the biological degradation of soil carbon. Surprisingly, while the low power solar cycles (viz. ~22 yr and ~2.4 yr) are seen in the $\delta^{18}O$ and $\delta^{13}C$ spectra where the ~21 yr cycle dominates, the stronger ~11 year cycle is only weakly represented in the proxy record, confirming earlier findings from a more limited data set.

(R. Ramesh and M. G. Yadava)

Temporal variation in Sr and $^{87}Sr/^{86}Sr$ of the Brahmaputra and their implications:

Impact of the highly variable discharge (almost 80% occurring during monsoon) on the river chemistry of the Brahmaputra was assessed by analyzing biweekly samples at Guwahati for Sr isotopes.

The decrease in the elemental abundance was twice the increase in discharge, indicating enhanced erosion during monsoon. This is attributable to a cumulative effect of increase in drainage area and in physical weathering during monsoon. $^{87}Sr/^{86}Sr$ and other proxies of silicate weathering show relatively lower contribution from silicate weathering during monsoon with concomitant increase in carbonate weathering contribution. Shorter interaction time between water and minerals during monsoon coupled with the slower weathering rates of silicates compared to carbonates are the likely contributors to the seasonal changes in major ion composition of river waters.

This study shows that in tropical India, where river discharge is governed mostly by monsoon rains, the annual elemental fluxes during monsoon can be a good approximation for their discharge weighted annual fluxes.

The chemistry sample of the sample collected on June 15, 2000 was anomalous, but similar to those from Tibetan region. This suggested contribution from a flash flood in the Brahmaputra due to a natural dam burst in Yigong River of Tibet. A water flux of ~50×10^6 l sec^{-1} was calculated for the flood, of which nearly half was from Tibetan drainage. These results highlight the use of chemical and isotopic composition of the water to quantify the source and discharge of flash floods.

(S. K. Singh and S. K. Rai)

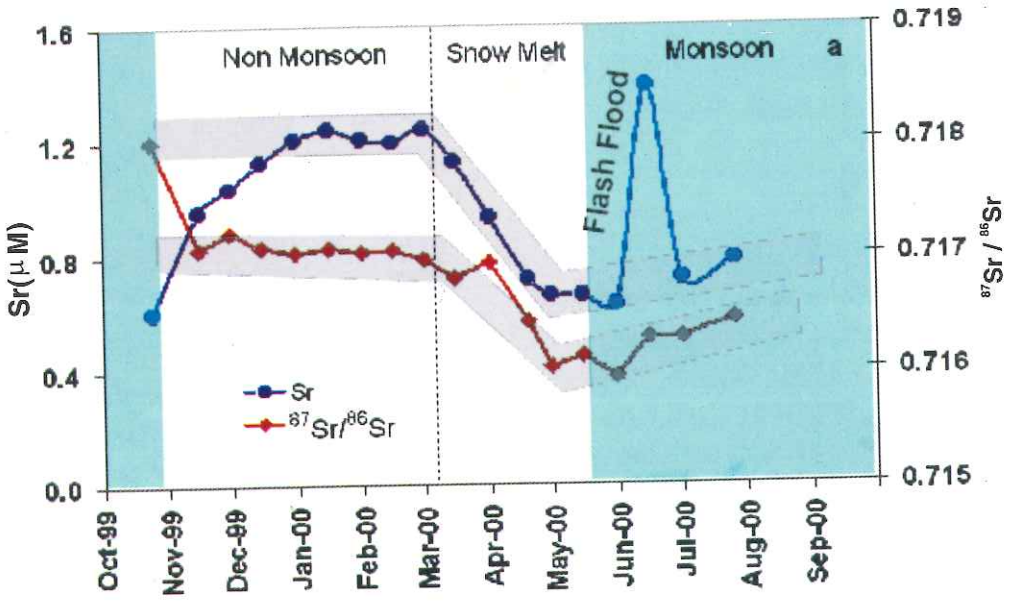


Fig. 6.8 : Temporal variation in dissolved Sr and its $^{87}Sr/^{86}Sr$ of the Brahmaputra at Guwahati.

Chemical weathering, calcite precipitation and carbon cycle in the Ganga Basin

An attempt was made to resolve the issue of calcite precipition silicate weathering and CO_2 consumption rates in the Ganga basin by measuring Ca,Sr $^{87}Sr/^{86}Sr$ of river waters, evaporites and precipitated carbonates from the Ganga drainage. Results show that an average of ~85% of the initial calcium is lost by precipitation of calcite. If such loss of Ca indeed is prevalent then the supply of Ca by weathering should be 5-6 times more than that derived from the water data alone. Further more, the bed-load sediments of the Ganga are poorly weathered and represent the source rocks whereas suspended load have CIA (Chemical index of alterations) values of ~54 and ~70 indicating intense chemical weathering. The difference in elemental abundances between suspended sediments and bed load were used to estimate the chemical weathering flux. The results show that weathering fluxes derived from sediment and water data are within a factor of ~2.

The scatter plot of POC vs. Al show that the bed load, suspended load and the < 4mm fraction fall in three distinct groups (Fig. 6.9). Al is relatively enriched in finer particles, and is interpreted in terms of an inverse relation between organic carbon abundance and particle size. Adsorption of organic matter on clay mineral and fine particles which have larger surface area can contribute to the trend in Fig. 6.9.

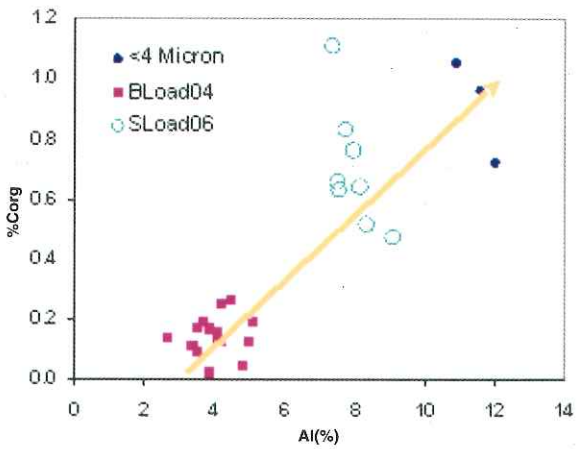


Fig. 6.9 : Variation of particulate organic carbon with Al

These studies provide an estimate of ~4 million tons/y of POC to the Bay of Bengal and most of it (80%) is transported via suspended load. The POC flux for the Ganga is ~ 2% of its global supply via rivers to the world oceans and is of similar magnitude to that of CO_2 consumption by silicate weathering. The burial of riverine POC in deltaic and coastal sediments is a key component of carbon cycle. If 50% of the POC from the Ganga gets buried in deltaic sediments of the Bay of Bengal, then the total carbon sink for the Ganga basin would be ~$6x10^5$ mole C km^{-2} yr^{-1}.

(Sunil Singh, S. K. Rai and S. Krishnaswami)

Paleoerosion in the Ganga basin

The temporal variation in the weathering intensity in the Ganga basin can provide information about the impact of Himalayan orogeny on the climate change. Data on variation in erosion in the Ganga basin during the past is scanty. A study has been initiate to track the erosion variability (if any) over 100 ky time scale in the Ganga basin. Samples from a sediment core (raised by IIT Kanpur) were analyzed for their chemical composition and for Sr and Nd isotopes. $^{87}Sr/^{86}Sr$ and ε_{nd} in the silicate fraction of the sediments show one in the range of 0.72701 to 0.76708 and -16.6 to -14.4, respectively, indicating change in provenance of these sediments with time. $^{87}Sr/^{86}Sr$ of carbonates in the same core vary from 0.71419 to 0.71889 suggesting temporal variation in dissolved $^{87}Sr/^{86}Sr$.

This work was done in collaboration with S. K. Tondon, Delhi Univ. and Rajiv Sinha, IIT Kanpur.

(Waliur Rahaman and Sunil K. Singh)

Past Climate from isotopes and chemistry of ground waters

To understand the hydrological imprints of past climate change, isotopic ratios of oxygen and hydrogen in groundwater and precipitation from North Gujarat-Cambay region were measured.

The amount weighted average values of *d*-excess (1.2 ± 4.8 ‰) as well as the slope (7.6) and the intercept (-2.9) of the local meteoric water line (LMWL) are lower than that for Global Meteoric Water Line (GMWL). These values are interpreted as imprints of evaporation from falling raindrops under the present semi-arid climatic regime.

The average value of *d*-excess of groundwater samples is lower than that for precipitation samples. The average values of $\delta^{18}O$ and δD for ground water are higher compared to that for precipitation and also have relatively narrower range. This indicates mixing of rain water from different events in the soil zone and additional evaporation during its infiltration.

The groundwater in the region has distinctly higher $\delta^{18}O$ values and lower d-excess values compared to surrounding area. Radiocarbon ages of 20 ± 5 ka BP indicated its recharge around Last Glacial Maximum (LGM) with increased aridity and lower rainfall. Higher electrical conductivity and ionic concentration of groundwater in the same region corroborates the inference of enhanced evaporation due to increased aridity and additionally suggest the possibility of increased dry deposition.

(R.D. Deshpande, S.K. Gupta, R.A. Jani, D.K. Rao)

Development of Groundwater CFC analytical Capability

An ongoing endeavor of setting up a Gas Chromatography laboratory for analyzing dissolved Chlorofluorocarbons (CFCs) in groundwater was accomplished for the first time in India. The CFCs provide a useful tracer for detecting the groundwater recharged after these were introduced into atmosphere in early 1940s.

A purge and trap system for extracting dissolved CFCs from groundwater samples was developed and protocols for sampling and storage of water samples in the field, extraction of dissolved CFCs and their chromatographic analyses have been developed and are ready for field investigation.

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

Geochemistry of Newania carbonatites, Rajasthan

Of the twenty major Indian carbonatite complexes, Newania (N 24°38°, E 74°03°) of Rajasthan is the only known dolomite carbonatite. An intriguing aspect of Newania is that unlike most carbonatites worldwide, it is not associated with alkaline silicate rocks. Extensive field geochemical, and isotopic investigation of the complex suggest multiple intrusive events. Major and trace element concentrations indicate extensive fractional crystallization of the parental magmas. Sr isotope systematics suggests the possibility of at least two generations of intrusions, one with an initial $^{87}Sr/^{86}Sr$ in the range of 0.70199-0.70231 and the other with 0.70318-0.70344. These ratios confirm that Newania carbonatites are mantle derived, and a large ion lithophile element depleted mantle was the source for these magmas. Stable C and O isotope compositions also support their magmatic nature. In a $\delta^{13}C$ versus $\delta^{18}O$ co-variation diagram (Fig. 6.10) it is observed that most of the dolomite carbonatites plot in the "primary carbonatite" field. Application of the multi-component Rayleigh fractionation model to these primary values suggest that the dolomite carbonatites have fractionally crystallized from a carbonate magma(s) having initial compositions of $\delta^{13}C$ = -4.6 and $\delta^{18}O$ = 8.3±1.5 ‰ (the mean values of observed distributions in dolomites) at a temperature of 700°C. This implies that the mantle source compositions of the Newania carbonatites would have been: $\delta^{13}C$ = -4.6 ‰ and $\delta^{18}O$ = 6.3 ‰ (2 ‰ lower than that of the magma).

(J.S. Ray and A.D. Shukla)

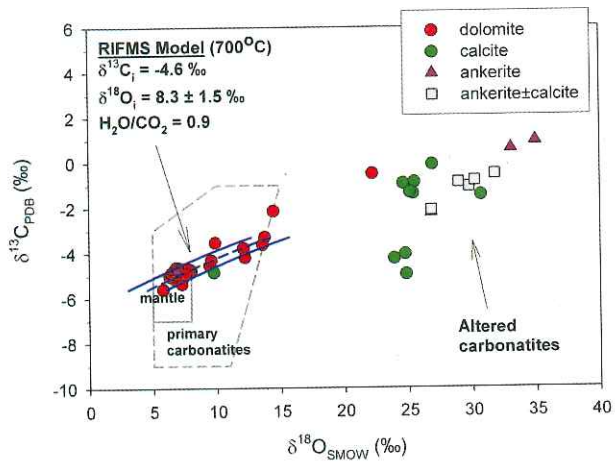


Fig. 6.10 : $\delta^{13}C$ vs. $\delta^{18}O$ values of Newania carbonatites carbonates are compared with multi-component Rayleigh fractionation model curve (dashed curve). The solid curves are the model curves that represent ±1.5 ‰ variation in the $\delta^{18}O$ of the magma. Also shown are the fields for mantle and primary carbonatites.

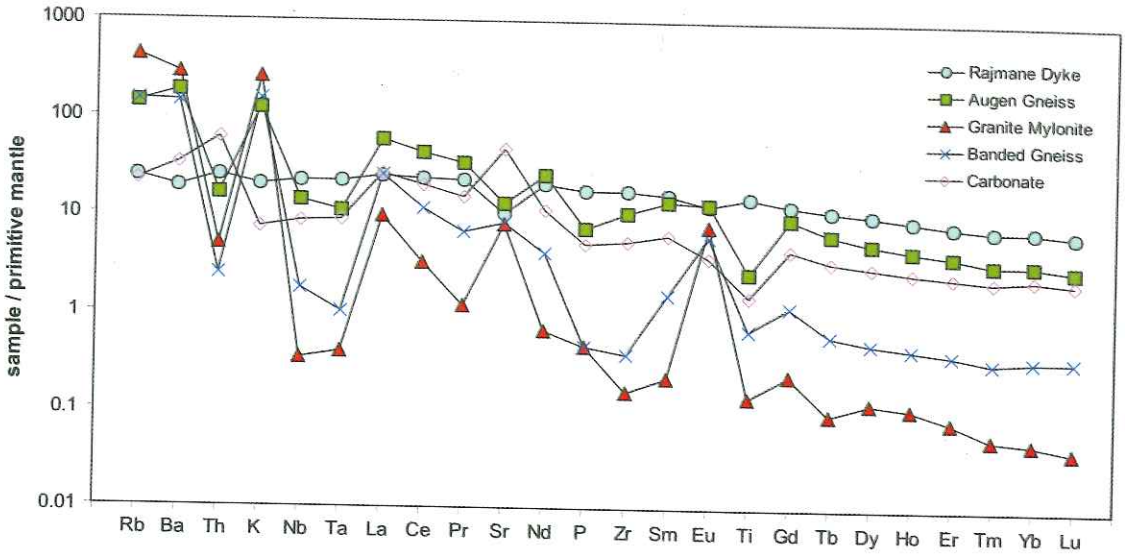


Fig. 6.11 : Primitive mantle normalized multi-element patterns for the xenoliths and the host Rajmane dyke from the Deccan Traps, Maharastra. The normalizing values are from Sun and McDonough, Geol. Soc. Lond. Spec.405 Publ. 42, 313-345 (1989).

Characterization of the Deccan basement through xenoliths

Xenoliths in lavas and intrusions provide the most direct evidence on the composition of the crustal and mantle rocks through with these melts pass though. To characterize the basement directly beneath the Deccan Traps, some newly discovered crustal xenoliths from two basaltic dykes (Rajmane and Talwade dykes, Maharastra) in the central Deccan were analysed. Major and trace element concentrations and Sr isotope suggests that the xenoliths are from a lithological variety comprising gneisses, quartzites, granite mylonite, felsic granulite, carbonate rock, tuff, and represent small-scale lithological heterogeneity of the basement. Normalized multi-element patterns for the xenoliths and a host dyke are shown in (Fig. 6.11). Measured $^{87}Sr/^{86}Sr$ ratios in the xenoliths range from 0.70935 (carbonate) to 0.78479 (granite mylonite). The Rajmane dyke has a present-day $^{87}Sr/^{86}Sr$ ratio of 0.70465 and initial (at 66 Ma) ratio of 0.70445. This suggests low crustal input despite the abundant xenoliths. This is consistent with the trace element pattern. The dyke is subalkalic and fairly evolved (Mg No. = 44.1) and broadly similar in its Sr-isotopic and elemental composition to some of the lavas of the Mahabaleshwar Formation.

(A.D. Shukla and J.S. Ray)

Internal distribution of heavy oxygen isotopes in ozone

Ozone produced in Stratosphere and that produced in the laboratory shows an anomalous enrichment of heavy oxygen isotopes relative to oxygen from which it is formed. Both ^{17}O

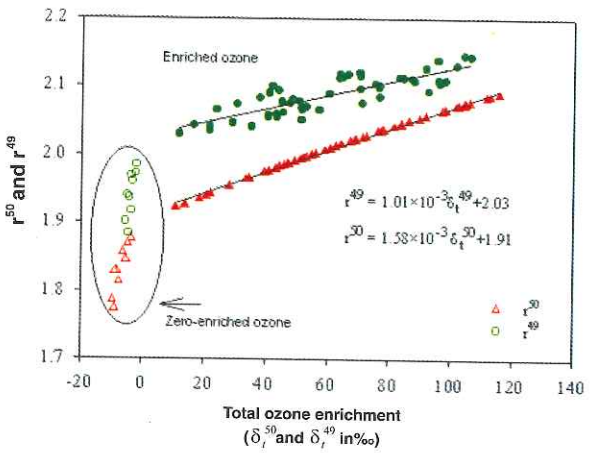


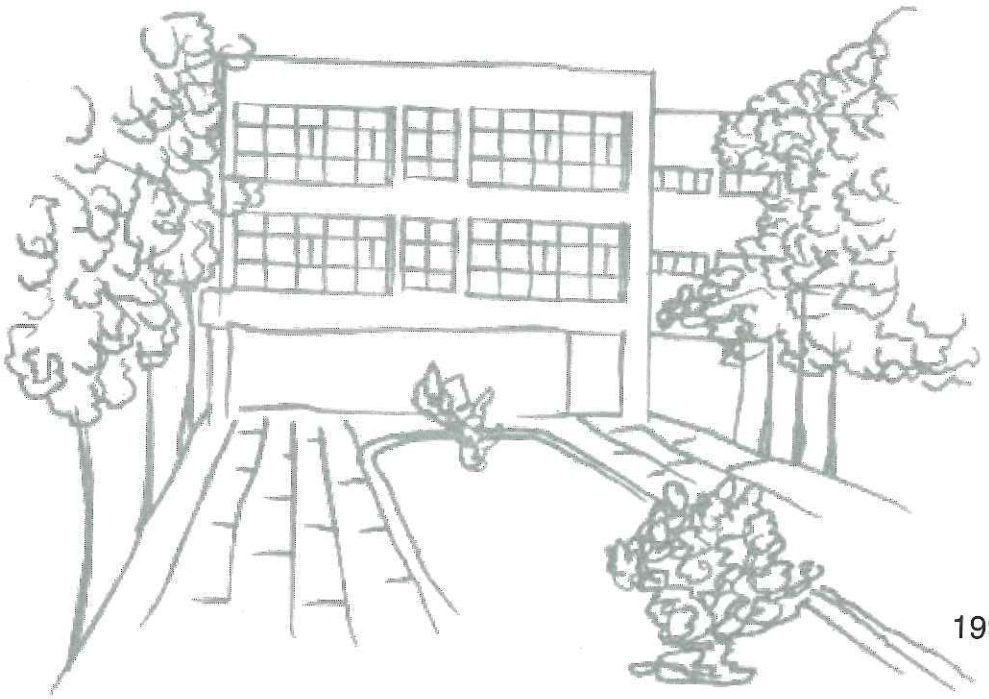
Fig. 6.12 : The ratio of asymmetric to symmetric species for $^{18}O^{16}O_2$ and $^{17}O^{16}O_2$ (as defined in terms of r-values) plotted against the bulk ozone enrichment. The values of r^{49} are more than those of r^{50} indicating different internal distribution of isotopes ^{18}O and ^{17}O in $^{18}O^{16}O_2$ and $^{17}O^{16}O_2$ isotopologues.

and ^{18}O are enriched by ~ 100 ‰ and surprisingly, $\delta^{17}O$ is not half of $\delta^{18}O$ as expected for normal mass dependent fractionation process. A heavy isotopologue of ozone (having a triangular shape) like $^{18}O^{16}O_2$ can have ^{18}O located either at the central position ($^{16}O^{18}O^{16}O$, symmetric type) or at the terminal position ($^{16}O^{16}O^{18}O$, asymmetric type). Statistically, asymmetric type ozone is expected to be twice more abundant compared to symmetric type ozone and thus their ratio, r^{50} = $[^{16}O^{16}O^{18}O]/[^{16}O^{18}O^{16}O]$ should be two. However, laboratory measurements indicate that this rule is violated in case of enriched ozone.

The intramolecular distribution of heavy isotopes in ozone is of interest as it bears directly on the issue of heavy isotope transfer from ozone to other oxygen-bearing molecules in stratosphere. Earlier spectroscopic studies dealt with intramolecular distribution in case of ^{18}O but ^{17}O studies was not investigated. We used a new approach based on oxidation reaction of ozone with silver metal to determine the ^{17}O distribution. In this method, the heavy isotope ratios $^{18}O/^{16}O$ and $^{17}O/^{16}O$ of silver oxide and ozone are measured and in conjuction with information of r^{50} to determine r^{49} = $[^{16}O^{16}O^{17}O]/[^{16}O^{17}O^{16}O]$ is defined. r^{49} increases with total enrichment in ozone just as in case of r^{50} (Fig. 6.12). Also, r^{49} values are significantly greater than r^{50} values. Asymmetric ^{17}O-species are more enriched by 10 to 15 ‰ whereas symmetric ^{17}O species are less enriched by 20 to 35 ‰. The difference between the two enrichments decreases with increase in total ozone enrichment.

For ozone samples having no enrichment, the symmetric species have relatively more heavy isotopes (for both ^{17}O and ^{18}O) than the asymmetric ones in contrast to the case of enriched ozone. The r-values in these cases are always less than 2.00 as expected from simple bond strength consideration. This information can now be used to model the mass independent enrichment of several atmospheric trace gases caused by transfer of isotopes from ozone.

(S.K. Bhattacharya and Antra)



1990

FACILITIES

Facilities

Computer Centre

The Computer Centre at PRL is equipped with (1) IBM Power 5 Machine having 4 processors and 8GB RAM, (2) four HP servers, each with Four AMD processors, 4 GB RAM, 1.5 TB disk space providing computing power with large disk storage, (3) 2 Dual Processor Xeon based servers providing additional computing power, and a total of 500GB disk space. All these computing machines are connected to a high-speed (100/1000 Mbps) local area network (LAN) that connects more than 200 PC's and workstations at Main campus, Udaipur Solar Observatory, Mt. Abu Telescope Station and Thaltej campus. The Udaipur Solar Observatory (USO) is connected to the main campus at Ahmedabad via a 64Kbps BSNL Leased Line. The main campus-Mt.Abu link has been recently upgraded from 64 Kbps to 2 Mbps MLLN link provided by BSNL, and Thaltej campus link has been upgraded from 2 Mbps to 40 Mbps over a 5.4 GHz microwave, using a non-line of sight Link. These provide constant connectivity. In addition the main campus and the Thaltej campuses are connected via BSNL's 2 Mbps MLLN for voice communication providing intercom telephone facility between the campuses.

The Centre provides centralized virus-free e-mails by automatically scanning all incoming e-mails. Anti-Spam filter has been centrally installed to block 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.

PRL SPACENET connectivity for Data, Intranet, and video conferencing has been established to interact with ISRO centers. Application software for mathematical, numerical and visualizations like IMSL, IDL, Mathematica, SigmaPlot, MATLAB, Lahey FORTARN 95, and Data Explorer etc. have been installed.

Library and Information Services

Library and information services at PRL play a crucial role in facilitating research in the laboratory by making available latest books, journals, e-journals in the respective areas. In addition

to procuring these, PRL Library subscribes to full-text databases like SienceDirect, IOP Archive, PROLA, Scientific American Online Archive. The library also provides document delivery service through Inter Library Loan (ILL) and through a commercial vendor – STN. The users are informed about the 'Recent Arrivals' of books through email.

During 2006-07, 216 Scientific and Technical books, 121 Hindi books and 82 CDs/DVDs were added. Presently PRL Library holds a collection of 18188 books at Ahmedabad, 2056 books in USO library and 1697 Hindi books and 832 A-V items. Out of the 148 journal titles subscribed by the library 137 are available online. The library catered to 179 ILL requests of other institutes and 106 of PRL Scientists.

This year, through the Forum for Resource Sharing in Astronomy and Astrophysics (FORSA) Consortium, PRL Library began subscribing to Astronomical Journal, Astrophysical Journal and Astrophysical Journal Supplement.

Workshop

PRL workshop is a general-purpose machine and fabrication shop that provides extensive support to scientists and engineers. The workshop has a wide range of machines such as metal cutting machines, welding machines and a CNC lathe machine. The workshop plays an important role in designing, developing and manufacturing the precise mechanical components and helps the scientists to establish various systems for different experimental programme. The workshop also carries out the sheet and structural metal fabrication jobs. The high vacuum welding joints also carried out by using TIG welding machine. The Workshop is equipped with one CNC lathe machine to carry out precise turning jobs. Various lens adaptors, optical components and mounts were fabricated for USO.

Fabrication Jobs

Installation of the Telescope in Dial- Lab.

For Dial-Lab, the structure for mounting telescope, a guide to move the telescope, filter housing and various mechanical components were designed and fabricated in the workshop.

Swagelock-Cajon Couplings

In the plumbing of the extraction and injection system of the Gas Chromatograph (GC) laboratory, there are a few joints where a glass tube is connected to an SS tube. The usual Swagelok couplers for Stainless Steel (SS) tubes have two SS ferrules which tightly grip and seal the tube whereas usual Cajon couplers have o-ring on a metallic stub which tightly grip and seal the glass tube.

In GC laboratory, the requirement of coupling a glass tube to an SS tube, was meet by using a unique coupler, that had a Swagelok type connection on one side and Cajon type connection on another. Also, the port sizes on the two sides of these couplings are different such that these couplings also act as reducing unions. Such combination couplers are not available commercially in the market. The workshop fabricated such couplings with very precise machining work. More than 32 assemblies for the two sizes 1/2" to 1/16" Swagelok-Cajon and 3/8" to 1/16" Swagelok-Cajon combination unions was manufactured and tested both in vacuum and pressure systems. This unique coupler made on C.N.C lathe will be of great use to all those who want to unite glass tube with SS tube in their experimental set up.

Sampling Pipe Holders For Luminescence Dating

Reusable Sampling Pipes for Luminescence Dating were designed and fabricated. This Design effectively met the requirement of a rugged, re-usable, easy to use in difficult terrains, light tight and moisture tight sampling tube. The system has aluminum and galvanize pipes sharpened at one end so as to provide easy penetration in sediments. This can be sealed with a Al. Cap with a neoprene O-ring to ensure perfect moisture seal. The design of cap is such that it push fits on the sampling pipe. The second end is sealed with a stepped mild steel stub with a rivet pin so as to provide sufficient strength for pushing the pipe with a geological hammer.

Langmuir Sensor Probe For Abha

ABHA is Rocket borne Experiment to measure:

(a) a number of nightglow Emissions and

(b) The electron density using a Langmuir Probe.

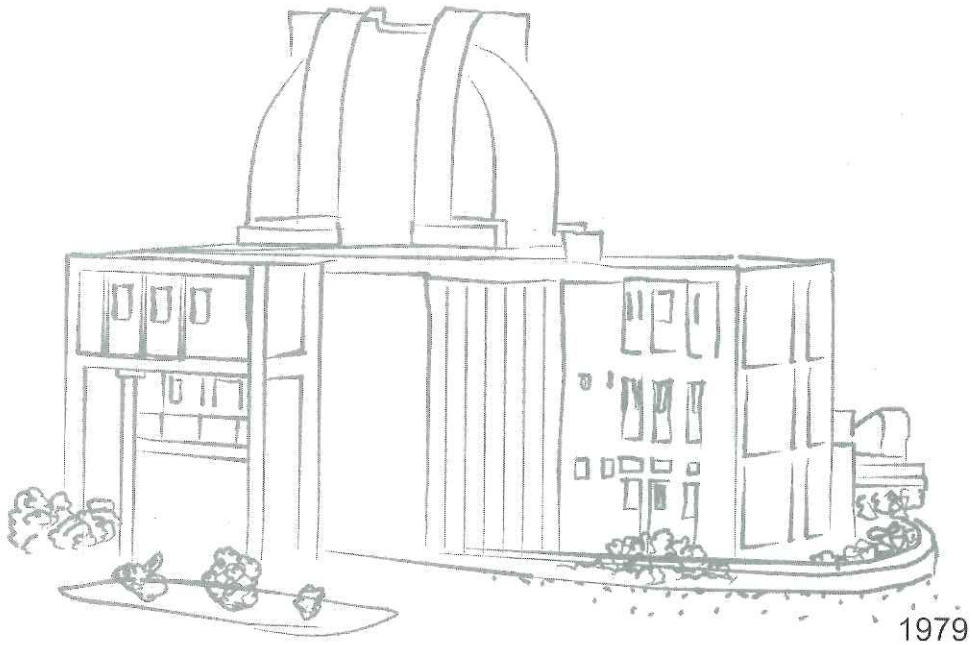
On a C.N.C lathe machine we manufactured a Langmuir probe

sensor which was used for measuring electrons fluxes. Langmuir probe sensor are used for rocket borne experiment to measure the atmospheric and mesospheric electrons.

The design of the L.P. Sensor was complex and could not be manufactured on conventional lathe machines. A special Face Grooving Tool was made for machining of Internal Radius. Machining of outer radius was done using a button tool. These male and female piece were combined to give a L.P.Sensor.

Other important jobs were:

- Clamps and mounts for holding diaphragms
- Adjustable motor mount
- 'U' – shape holder for fixing a camera stand
- Cf-63 flange with ¼" gas pipe & capillary
- Gun holders
- Parts of PE spectrometer
- Parking stand for PRL staff quarters



1979

HONORARY FELLOWS

Honorary Fellows

Professor J.E. Blamont

Academician V.L. Ginzburg

Professor A.M.J. Tom Gehrels

Professor D. Lal, FRS

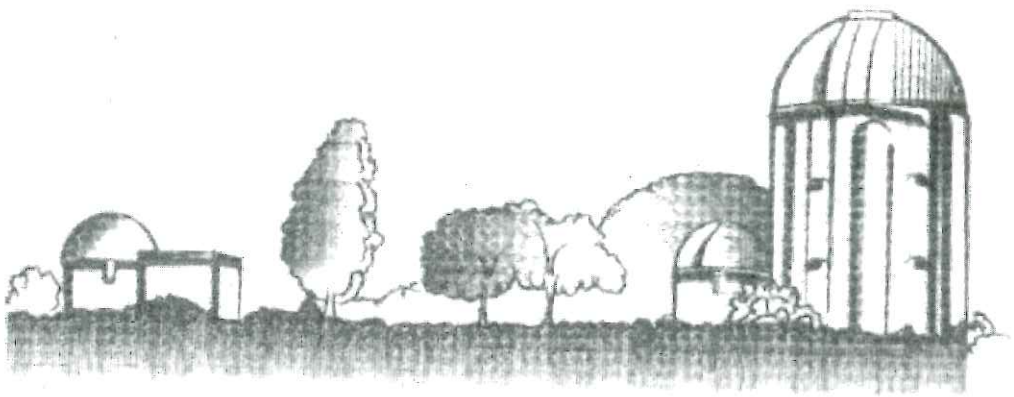
Professor M.G.K. Menon, FRS

Professor U. R. Rao

Professor P. Crutzen

Professor K. Kasturirangan

Professor A. Hewish



1980

ACADEMIC FACULTY

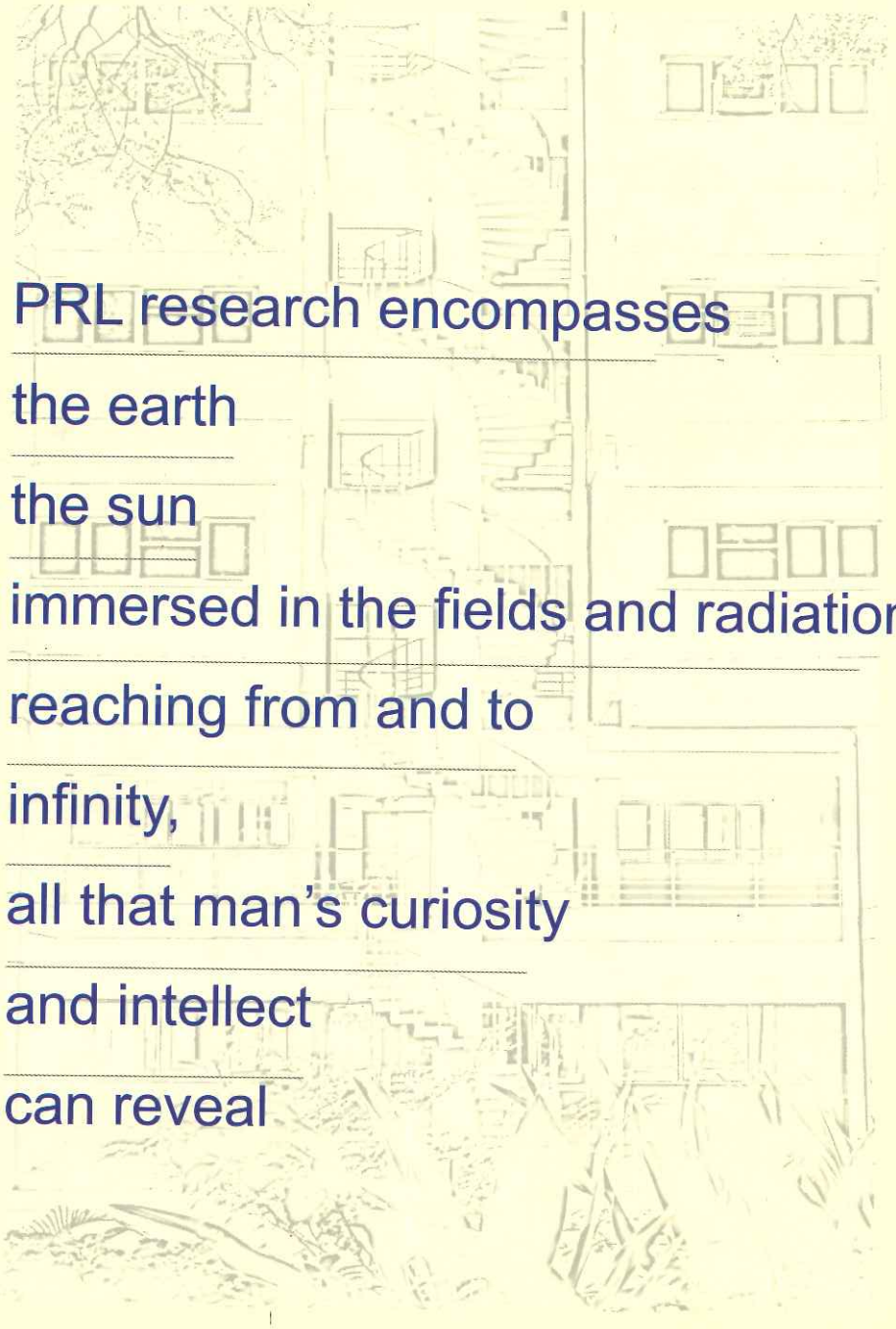
Academic Faculty

Name	Designation	Specialisation	Academic Qualification
DR. GOSWAMI J N FNA, FASc, FNASc, FTWAS	Director	Solar System Studies (Pre - Solar Processes)	Ph D PRL, Gujarat Univ. (1978)
DR. AMBASTHA A K	Professor	Solar Plasma Physics, Coronal Structure and Polarization	Ph D PRL, Gujarat Univ. (1981)
DR. AMRITKAR R E FASc	Professor	Nonlinear Dynamics & Chaos	Ph D IISc, Bangalore (1978)
DR. ASHOK N M	Professor	Close Binary Stars, Novae, IR spectroscopy	Ph D PRL, Gujarat Univ. (1983)
DR. BALIYAN K S	Associate Professor	AGNs, Comets, Atomic Physics, Milky Way	Ph D Roorkee Univ. (1986)
DR. BANERJEE D	Reader	Thermoluminscence & Planetary Physics	Ph D PRL Gujarat Univ. (1996)
DR. BANERJEE D P K	Associate Professor	Novae, Be Stars, Planetary Nebulae, IR and Optical Studies	Ph D PRL, Gujarat Univ. (1991)
DR. BANERJI J	Associate Professor	Laser Physics	Ph D City Univ.(New York)(1982)
DR. BAPAT BHAS	Reader	Atomic Collisions	Ph D TIFR, Mumbai Univ. (1997)
DR. BHATT J R	Reader	Astrophysics	Ph D IPR, MS Univ. (1992)

DR. BHATTACHARYA S K FASc, FNASc	Senior Professor	Isotope Geochemistry	Ph D PRL, Gujarat Univ.(1980)
DR. CHAKRABORTY A*	Reader	Extra-solar planets, Star Formation & Instrumentation	Ph D PRL, Gujarat Univ. (1999)
DR. CHAKRABORTY S*	Reader	Stable Isotope mass-spectrometry	Ph D PRL, Gujarat Univ.(2004)
DR. CHANDRASEKHAR T	Professor	High Angular Resolution Studies, Late type stars, Solar Coronal Studies, Comets	Ph D PRL, Gujarat Univ. (1982)
DR. GHOSH D K *	Reader	Particle Physics	Ph D Bombay Univ. (2000)
DR. HAIDER S A	Associate Professor	Planetary and Cometary Atmospheres	Ph D Banaras Univ. (1984)
DR. JAIN R	Associate Professor	Solar Physics	Ph D PRL, Gujarat Univ. (1983)
DR. JANARDHAN P	Associate Professor	Solar Radio Astronomy & Space Weather	Ph D PRL, Gujarat Univ. (1992)
DR. JAYARAMAN A FASc	Professor	Atmospheric Aerosols and Radiative Studies	Ph D PRL, Gujarat Univ. (1985)
DR. JOSHI U C	Professor	AGNs, Milky way, Star Formation and Comets	Ph D Kumaun Univ. (1981)
DR. JOSHIPURA A S FNA, FASc, FNASc	Senior Professor	Particle Physics	Ph D Bombay Univ. (1979)
DR. KOTA V K B	Senior Professor	Nuclear Physics	Ph D Andhra Univ.(1977)
DR. LAL SHYAM FNA, FASc	Professor	Atmospheric Chemistry of Trace Gases	Ph D PRL, Gujarat Univ. (1982)
DR. MAHAJAN NAMIT*	Reader	Particle Physics	Ph D Delhi Univ. (2003)
DR. Ms. MARHAS K K *	Reader	Solar System studies	Ph D PRL (2001)
DR. MATHEW SHIBU K	Reader	Solar Magnetic & Velocity Fields	Ph D PRL, Gujarat Univ. (1999)
DR. MISHRA H	Reader	Strong Interaction Physics & Nuclear Astrophysics	Ph D IOP, Utkal Univ. (1994)
DR. MOHANTY S	Associate Professor	Astroparticle Physics	Ph D Wisconsin Univ. (1989)
DR. MURTY S V S FASc	Professor	Isotope Cosmochemistry	Ph D IIT, Kanpur (1981)
DR. NAIK S*	Scientist-SD	High Energy Astro-physics, X-ray Binaries	Ph D TIFR, Mumbai Univ. (2003)
DR. PANIGRAHI P K	Associate Professor	Field Theory	Ph D Rochester Univ. (1988)
DR. RAMESH R FNA, FASc, FNASc	Professor	Paleoclimatology, Oceanography & Modelling	Ph D PRL, Gujarat Univ. (1984)
DR. RAI VINAI*	Reader	Stable Isotope Cosmochemistry	Ph D PRL, MS Univ. (2001)
DR. RAMACHANDRAN S	Reader	Atmospheric Aerosols Radiative & Climate Impacts	Ph D PRL, MS Univ. (1996)

DR. RANGARAJAN R	Reader	Particle Physics & Cosmology	Ph D Univ. of California, Santa Barbara (1994)
DR. RAO B G A	Senior Professor	Star formation, Planetary Nebulae, AGB Stars and Imaging Fabry Perot Spectroscopy	Ph D PRL, Gujarat Univ. (1978)
DR. RAY J S	Reader	Isotope Geochemistry	Ph D PRL, MS Univ. (1997)
DR. RINDANI S D	Senior Professor	Particle Physics	Ph D IIT, Bombay (1976)
DR. SANTHANAM M S	Reader	Non-linear Dynamics & Time Series Analysis	Ph D PRL, Gujarat Univ. (1999)
DR. SARIN M M FASc	Professor	Geochemistry and Oceanography	Ph D PRL, Gujarat Univ. (1985)
DR. SARKAR UTPAL FNA	Professor	Particle Physics	Ph D Calcutta Univ. (1984)
DR. SEKAR R	Associate Professor	Upper Atmospheric & Ionospheric Physics	Ph D PRL, Gujarat Univ. (1991)
DR. SHARMA P	Scientist-SF	Geophysics and Hydrology	Ph D PRL,Gujarat Univ.(1977)
DR. SHEEL VARUN	Reader	Modelling of Lower Atmosphere	Ph D PRL, Guj. Univ. (1996)
DR. SINGAL A K	Reader	Radio Astronomy & Astrophysics	Ph D TIFR, Bombay Univ.(1986)
DR. SINGH ANGOM D	Reader	Atomic Physics	Ph D IIA, Bangalore Univ. (1998)
DR. SINGH R P	Scientist – SE	Laser Physics	Ph D JNU, N. Delhi (1994)
DR. SINGH SUNIL K	Reader	Isotope Geochemistry	Ph D PRL, MS Univ. (1999)
DR. SINGHVI A K FNA, FASc, FNASc, FTWAS	Senior Professor	Palaeoclimatology and Geochronology	Ph D IIT, Kanpur (1975)
DR. MS. SRIVASTAVA N	Reader	Solar Physics	Ph D PRL, Ravi Shankar Shukla Univ. (1994)
DR. SUBRAMANIAN K P	Associate Professor	Experimental Atomic and Molecular Physics	Ph D PRL, Gujarat Univ. (1987)
DR. TRIVEDI J R	Scientist- SF	Isotope Geochemistry	Ph D PRL, Gujarat Univ. (1991)
DR. VADAWALE S V	Scientist – SD	High Energy Astrophysics and X-ray Spectroscopy	Ph D TIFR, Mumbai Univ. (2003)
DR. VATS HARI OM	Associate Professor	Space Weather & Radio Astronomy	Ph D PRL, Gujarat Univ. (1979)
DR. VENKATKRISHNAN P	Senior Professor	Solar Physics	Ph D Bangalore Univ. (1984)

*** Joined in 2007**



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