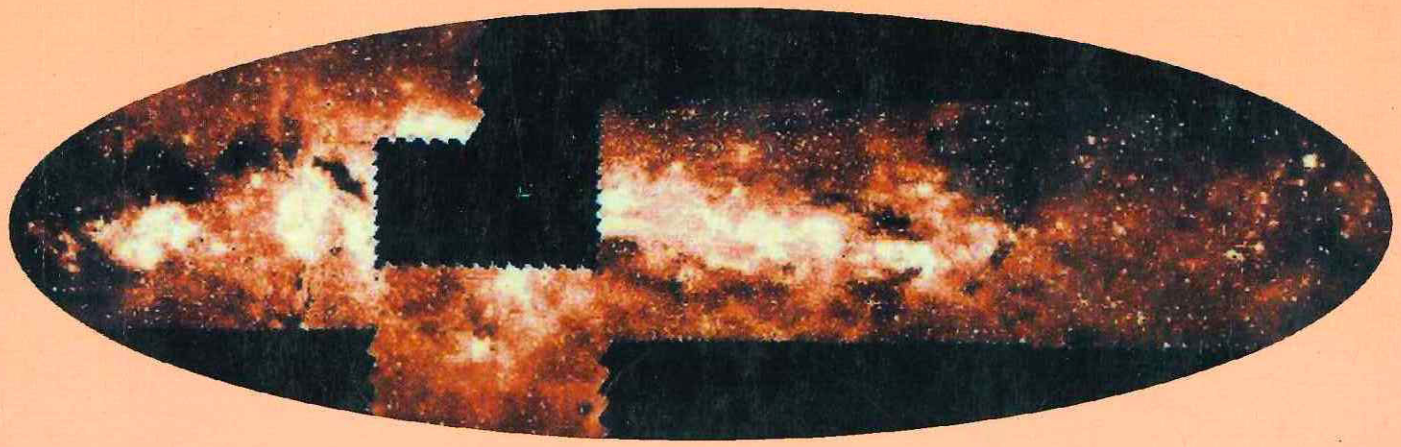
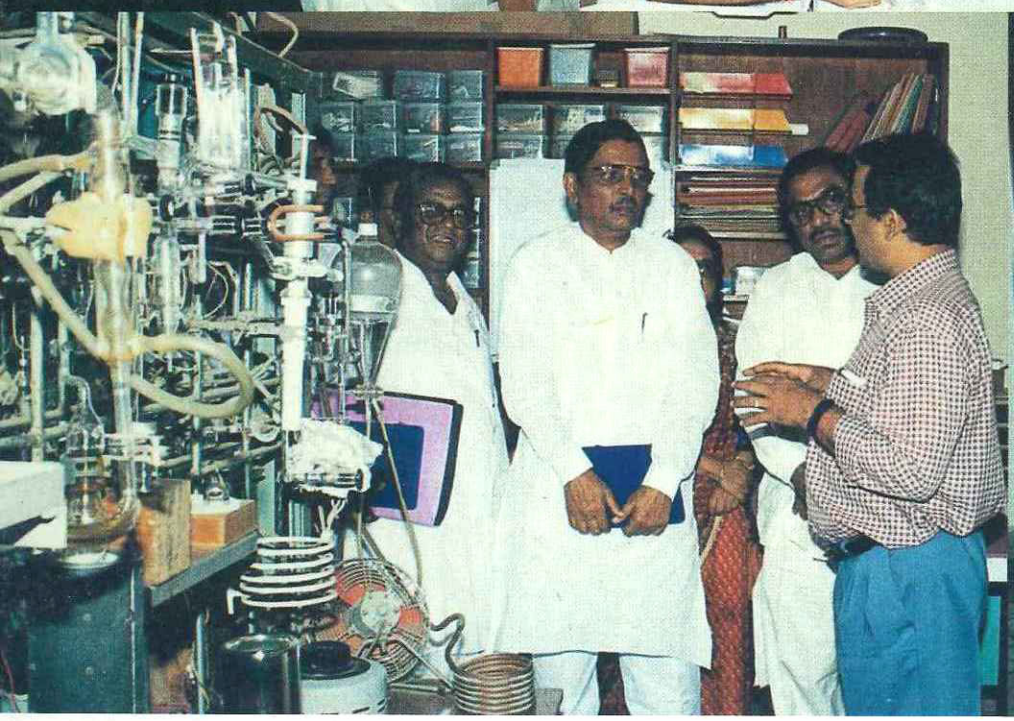
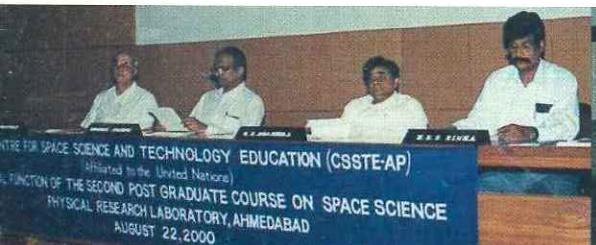
वार्षिक रिपोर्ट
Annual Report
2000-2001

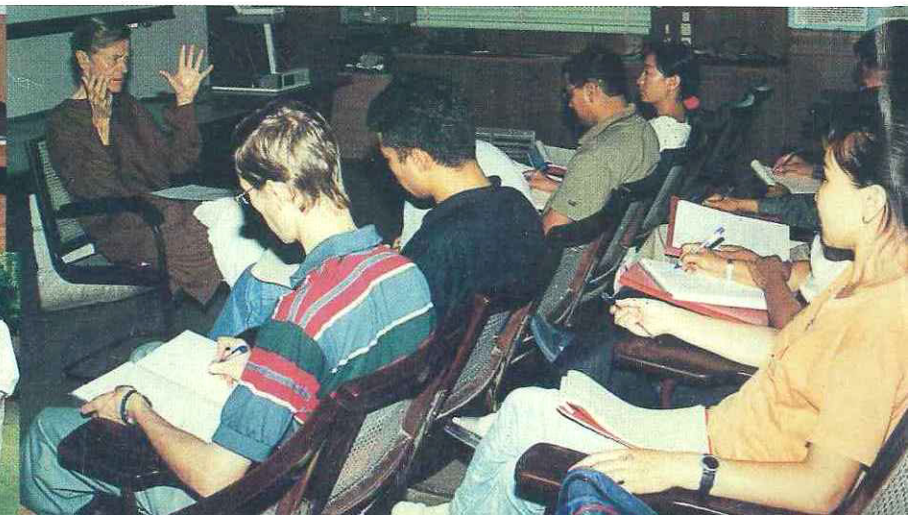


भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद

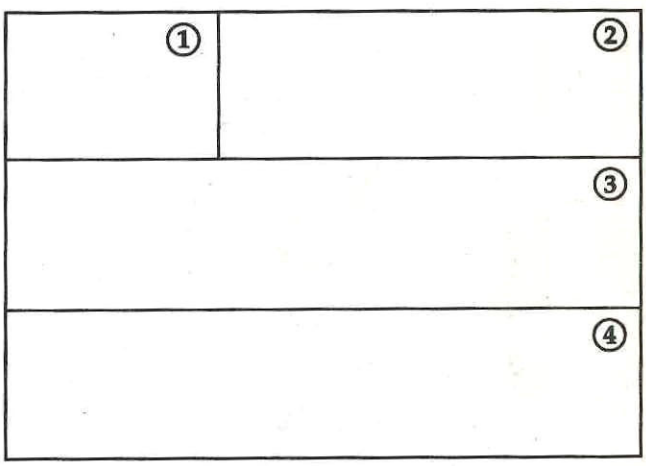
Physical Research Laboratory, Ahmedabad




SPACE SCIENCE AND TECHNOLOGY EDUCATION (CSSTE-AP)
Affiliated to the United Nations)
FUNCTION OF THE SECOND POST GRADUATE COURSE ON SPACE SCIENCE
PHYSICAL RESEARCH LABORATORY, AHMEDABAD
AUGUST 22,2000



वार्षिक रिपोर्ट
Annual Report
2000-2001



Title Cover :

The Centre of our Galaxy is hidden from optical view by dust and is a relatively unexplored region. Infrared light can more easily penetrate the dust and this view of the dense starfields towards the Inner Galaxy is a mosaic of observations at 7micron wavelength by the Infrared Space Observatory for the ISOGAL project. Huge obscuring dust clouds still crowd the area especially in the left part of the infrared image. The centre itself (marked by the white circle) is missing from the mosaic as it is so bright that it would saturate ISO's sensitive camera. What appears to be extended emission along the Galactic plane are thickly populated star clusters. The stars are mostly evolved red giants. These stars contribute to the interstellar gas and dust clouds, enriching their galactic environment with carbon and other elements. Their motions also trace the mass distribution in the Galactic Centre. This image was selected as the Astronomy Picture of the Day by the NASA website http://antwrp.gsfc.nasa.gov/apod/ap000629.html">

Inner Title Cover :

1. *Prof. V.Radhakrishnan delivering the sixteenth Prof. K.Ramanathan Memorial Lecture.*
2. *Recipients of the Shri Hari Om Ashram Prerit Vikram Sarabhai Research Awards and the PRL, Awards.*
3. *Members of the Parliamentary Standing Committee on Science and Technology, Environment and Forest visiting PRL.*
4. *Highlights of the Second Post Graduate Course on Space Sciences of the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTE-AP) affiliated to UN.*

Compiled and Edited by:
Dr. (Mrs.) P. Chakrabarty

Pictures by:
D.R. Ranpura

Published by:
Physical Research Laboratory,
Ahmedabd - 380 009

Layout by:
Mukesh Enterprise
Odhav Road, Ahmedabad - 382 415

Printed by:
Print Vision Ph. : (079) 6405200

Council of Management 2000-01

Chairman	
Professor U.R. Rao Member, Space Commission Department of Space	Nominee of the Government of India
Members	
Dr. K. Kasturirangan Chairman, ISRO / Secretary, DOS Department of Space	Nominee of the Government of India
Shri V. V. Bhat Joint Secretary Department of Space	Nominee of the Government of India
Sheth Shri Shrenikbhai Lalbhai	Nominee of the Ahmedabad Education Society
Shri Kartikeya V. Sarabhai	Nominee of the Karmakshetra Educational Foundation
Secretary, Department of Education Govt. of Gujarat Gandhinagar, Gujarat	Nominee of the Government of Gujarat
Prof. G.S. Agarwal (Ex-Officio)	Director Physical Research Laboratory
Secretary Shri M. R. G. Murthy (Ex-Officio)	Controller / Registrar Physical Research Laboratory

Contents

Introduction

The year 2000-01 opens a new millennium. As we begin the millennium, a new century and a new era is beckoning us. This annual report is the first of the new millennium; a millennium which would hopefully see the birth of fantastic ideas leading to the discovery of new path-breaking science.

The laboratory continued to contribute significantly in national and international scientific scene with its large number of first rate publications. A total of **one hundred and forty two** papers have been published, of which **one hundred and twenty three** were in international journals. During the year our scientists continued to participate actively in national and international conferences with large number of presentations out of which **seventy six** were invited review talks. At present PRL has thirty three research scholars and nine post-doctoral fellows working in various disciplines. **Five** Ph.D. theses were submitted. The topics covered were as diverse as Isotopic and Elemental Studies of Gondwana Carbonates and their Implications; New Coherence Effects in Systems with Near-Degenerate Levels Driven by Intense Laser Fields; Studies in Topics Going Beyond the Standard Electroweak Model; Novel Optical Phenomena Induced by External Control Lasers; Investigation in the Low Latitude Daytime Mesosphere Lower Thermosphere Region. A summary of scientific achievements is given on page 5 .

The laboratory's contribution to basic research in various fields has been recognised both nationally and internationally. Some of our scientists have received prestigious awards and honours such as the Fellowships of the Third World Academy of Sciences, Trieste, Italy; Indian National Science Academy, New Delhi; Indian Academy of Sciences, Bangalore and the International Meteoritical Society, USA.

In the new millennium the laboratory has initiated a few new and dynamic research programmes. One such programme is the Submillimeter Science and Technology Programme. Due to atmospheric absorption, the observations of the Universe in the submillimeter region (300GHz-4THz) can only be explored from high above the atmosphere and from space. A laboratory facility is under construction at PRL to support tunable high-resolution spectroscopy in the submillimeter wave region. This facility will help future science study missions on planetary atmospheres and astronomy.

PRL plans to put an experiment, the *Solar X-ray Spectrometer- SOXS* on board an Indian Satellite to measure X-ray spectrum of the Sun during the present solar cycle. Such measurements would pave the way to study the nature, different characteristics and the mechanism of certain solar flares. The experiment comprises of two independent payloads, namely SOXS Low Energy Detector (SLD) and the High Energy Detector (SHD). PRL will design, develope, fabricate and deliver the payload to ISRO. The Lab model of all the three packages of Low Energy Detector have been successfully designed, developed and fabricated, and an integral line test of the whole payload has been conducted at the Technical Physics Division, ISAC, Bangalore.

The *Indo-French collaboration* project initiated in October 1999, supported by the Indo-French Centre for Promotion of Advanced Research, New Delhi, is aimed at studying the inner region of the galaxy. Towards this goal, extinction maps for the inner region of the galaxy was constructed. Using the ISO data, images of the inner Galaxy were built at 7 and 15 micron which are being studied. Observations in JHK' band were also carried out from Mt. Abu Observatory for some selected regions. Data are being analysed.

A new programme of *measuring the non-mass dependent oxygen isotopic fractionation as a function of ambient pressure in ozone* formed by photolysis of oxygen by UV light has been initiated. The ozone is highly enriched in both ^{17}O and ^{18}O and the enrichment increases with decrease of oxygen pressure from 400 torr attaining a peak at about 15 torr pressure. These data will be useful in putting constraints on the various theories put forth to explain the anomalous isotopic enrichment in ozone in the stratosphere and also in the laboratory.

To address new problems in planetary sciences that could not be investigated earlier due to sample size constraints, a *laser probe noble gas mass spectrometry laboratory* has been successfully set up. The Nd-YAG laser

with 16W power at 1064 nm (CW) and about 3W power at 532 nm, procured from Spectron Lasers, U.K., has been used for heating sub-milligram samples for gas extraction. An all metal ultra high vacuum gas extraction system, assembled in-house, has been integrated with the mass spectrometer. The new extraction system gives system blanks for noble gases that are orders of magnitude lower than the glass extraction system coupled with conventional resistance/induction heating. Test runs with meteorite samples show that isotopic analysis of He, Ne and Ar is feasible in samples of about 100 mg.

A multi-institutional programme, the Coherent Radio Beacon Experiment (CRABEX) proposed on GSAT-2 by Space Physics Laboratory, Thiruvanantha - puram, in collaboration with PRL and Andhra University has been approved recently. The experiment consists of the transmission of coherent radio beacons at 150 and 400MHz. A chain of twelve receivers will be set up at different institutions and universities in India. PRL is one of the nodal centres for operation of the chain and will be responsible for the management of four stations. The CRABEX data will also form an important input for space weather studies.

Through concentrated efforts of scientists of PRL, Institute of Physics (IOP) Bhubaneswar and National Geophysical Research Institute, the augmentation of the accelerator at IOP, Bhubaneswar is now complete and it is currently undergoing trials for ^{14}C measurements. Since accelerator mass spectrometry ^{14}C dating needs samples in the form of graphite (~1 mg), two *graphitization systems* have been set up in PRL. Several graphite samples have been made and few of these have been sent to Arizona and Vienna for ^{14}C measurements. The measurements revealed that the standard and sample results are in excellent agreement with the expected/measured values. Some of these samples are currently being measured in IOP. The ^{14}C dating using the AMS is expected to be functional by the end of 2001.

PRL participated in the *Fourth International Radiocarbon Inter-comparison Program* in which samples of unknown ages and of different nature were distributed to eighty three institutions by the University of Glasgow. Participation in such exercises ensures the reliability of the results generated by us. We analyzed six samples which were wood, cellulose, humic acids and carbonates and our results agree well with the consensus values.

Prof. V. Radhakrishnan, Emeritus Professor and former Director of Raman Research Institute, Bangalore delivered the sixteenth Prof. K. R. Ramanathan Memorial Lecture entitled *Astronomy's Devices.*

The **Parliamentary Standing Committee on Science and Technology, Environment and Forests** comprising of fourteen MPs, from both Rajya Sabha and Lok Sabha, under the Chairmanship of Shri C. Ramachandriah and five Officers of their Secretariat visited Physical Research Laboratory, as a part of the on-the-spot study visit of the institutions under the administrative control of the Department of Space (DOS), Bangalore. The activities of the Laboratory were presented to the visitors.

Physical Research Laboratory honoured *seven distinguished scientists* on the occasion of the Vikram Jayanti. **Dr. S. K. Joshi**, former Director General of Council of Scientific and Industrial Research graced the celebration and gave away the *Hari Om Ashram Prerit Vikram Sarabhai Research Awards and the PRL Awards.* Five distinguished scientists received the Hari Om Awards and two received the PRL Awards.

The laboratory announced the *Hari Om Ashram Prerit Senior Scientist Award* for the year 2000 to the eminent scientist **Prof. C. N. R. Rao**, FRS, Linus Pauling Research Professor at the Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore and former Director of the Indian Institute of Science, Bangalore.

One of the highlights of our activities was the **Second Post Graduate Course on Space Sciences of the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTE-AP)** affiliated to UN. The Space Science Course is a two-stage programme leading to a M. Tech. degree in Space Science from the Andhra University, Visakhapatnam, India. The first stage of the course, which was of nine months duration

and consisted of Four Modules and a Pilot Project, was conducted at the Physical Research Laboratory (PRL), Ahmedabad from August 1, 2000 to April 30, 2001. The second stage of this course is of one-year duration and is being conducted in the home country of participants during 1st June 2001 to 31st May 2002. The Second Space and Atmospheric Science Course was inaugurated on August 22, 2000 by Prof. George Joseph, Distinguished Professor of the Indian Space Research Organization (ISRO) and former Director of the Space Applications Centre, Ahmedabad. Nine participants from five countries, one each from Kyrgyz Republic, Nepal and Uzbekistan, two from Mongolia and four from India, attended this course. The faculty for this course was drawn from PRL and other institutes and universities in India and abroad. The students learnt through lectures, discussions and extensive experimental work in different laboratories within PRL. After the completion of the first stage, a Valedictory Function was organized at PRL, Ahmedabad on April 29, 2001. Dr. A.E. Muthunayagan, Ex- Secretary, Department of Ocean Development, Government of India was the Chief Guest for the Valedictory function.

A symposium on **Space Science and Technology Advances and Applications to Society** was organised by PRL and the PRL Alumni Association during 24 - 25 October, 2000. About 200 leading scientists in space science, space technology and space applications participated. The topics covered were global change, weather satellites, monsoon rainfall; space astronomy; infrared, optical and sub mm wave astronomy; giant metrewave radio telescope; satellite communications and remote sensing. The symposium aimed to highlight the advances made in different fields, future programmes and applications to society. During the symposium, Dr.K. Kasturirangan, who turned sixty on October 24, 2000 was felicitated.

An international conference on **Perspectives in Theoretical Physics** was organized at PRL during January 8-12, 2001. The aim of the meeting was to focus on outstanding problems and emerging trends in theoretical physics. The major theme was divided in two main categories closely related to research activities of PRL: (a) High energy and astro-particle physics and (b) Quantum optics and nonlinear dynamics. The programme consisted of invited plenary review talks as well as specialized discussions through parallel sessions on each of the above topics. In addition, two of the sessions were devoted to poster presentations by young scientists. The discussions in (a) focussed on quantum gravity, neutrino physics and other topics beyond standard model namely, CP violation, theories with extra large dimensions, grand unified and supersymmetric theories. The discussion in (b) were on topics in quantum optics, such as, environmental produced dynamical evolution, quantum holography, quantum computer implementations with quantum optical systems. There were talks on quantum algorithms, entanglement and quantum chaotic systems, relaxation and fluctuation in quantum chaos, quantum mechanics of geometry and its applications. Some problems in strongly coupled dusty plasmas and on enquiries about the nature of space-time were also discussed. The meeting was attended by about one hundred participants of whom about a third were young researchers and students and about fifteen were scientists from abroad.

As a part of the National programme on Planetary Science and Exploration of ISRO, a **Workshop on Meteorites, Asteroids and Planets** was organized during February 26 to March 2, 2001, at PRL, Ahmedabad. About twentyfive participants consisting of M.Sc students, research scholars, post doctoral fellows and young teachers attended the workshop. Sixteen lecturers from PRL, USO, IISc, TIFR, IIA and Chandigarh University delivered lectures and tutorials. Solving assignments, presentations by the participants and laboratory visits formed the other component of this very interactive workshop. This workshop, was fully funded by ISRO.

In an effort to acquaint and educate the public on earthquakes, PRL, in association with the Indian National Science Academy arranged **two popular talks** by **Prof. Valdiya** after the devastating Gujarat Earthquake. The talks were entitled *The Earthquake in Tectonically Resurgent Kuchchh* and *Phir Tarap Uthi Gujarat Ki Dharitri*. In these talks he dealt with the causes of earthquake with special reference to the Indian subcontinent and

narrated the natural signatures of the impending earthquake that he noticed during a field trip to the Bhuj region a couple of weeks before the event and also deliberated on the difficulties in predicting earthquakes. He also dealt at length on the nature of possible aftershocks and precautions one should take to avoid damages and causalities during earthquakes. Both the talks received very enthusiastic response from packed audiences.

A College Teacher's Training Course on Mathematical & Computational Methods in Teaching Physics was organised at PRL during May 22 - June 9, 2000. The course consisted of lectures by the faculty members from the various divisions on topics decided for the course, project work, discussion sessions, visits to the various laboratories of PRL as well as to SAC and IPR. In addition, a popular lecture on *Deep Hot Biosphere* by **Prof. N. Bhandari** was also arranged. Ten college teachers participated in the course.

A **Summer Training Programme** for M.Sc. students was organised at PRL during May 15 - June 30, 2000. Twentyfive students from the various universities and IITs of the country were selected to participate in the programme. Each summer trainee worked on a specific project, either experimental or theoretical, under the supervision of a faculty member. A three-day trip was organised for the trainees to visit the Infrared Observatory at Mt.Abu and the Udaipur Solar Observatory at Udaipur. They were also taken around the various experimental facilities of the laboratory.

As a part of implementation and progressive use of Hindi in PRL, the **Hindi Week** was celebrated at PRL from September 11 - 17, 2000. The highlights of the celebration included word quiz, essay, elocution, Hamara Karya, self written poetry competitions and Antakshari. The special attraction of the celebration was a lecture by **Acharya Raghunath Bhatt**, Chairman of Gujarat Rastrabhasha Prachar Samiti, Ahmedabad who gave the inaugural lecture. The laboratory was awarded the **Vishesh Prashasti Patra** by Town Official Language Implementation Committee, Ahmedabad for using Hindi in Official and Scientific Activities and for also organising the National level Conference on Hindi and Internet in the New Millennium

I take this opportunity to thank all my colleagues including administrative, technical and supporting staff and also convey my appreciation to the PRL Council of Management for their guidance and advice in enabling the laboratory to pursue its goal of attaining scientific excellence.

G Sagarwal

Director

PRL in a Nutshell

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

i. Theoretical Physics;

ii. Nonlinear Dynamics and Computational Physics;

iii. Laser Physics and Quantum Optics;

iv. Astronomy and Astrophysics;

v. Planetary Atmospheres and Aeronomy;

vi. Earth Sciences and Solar System Studies.

The chart below profiles the scientific activities.

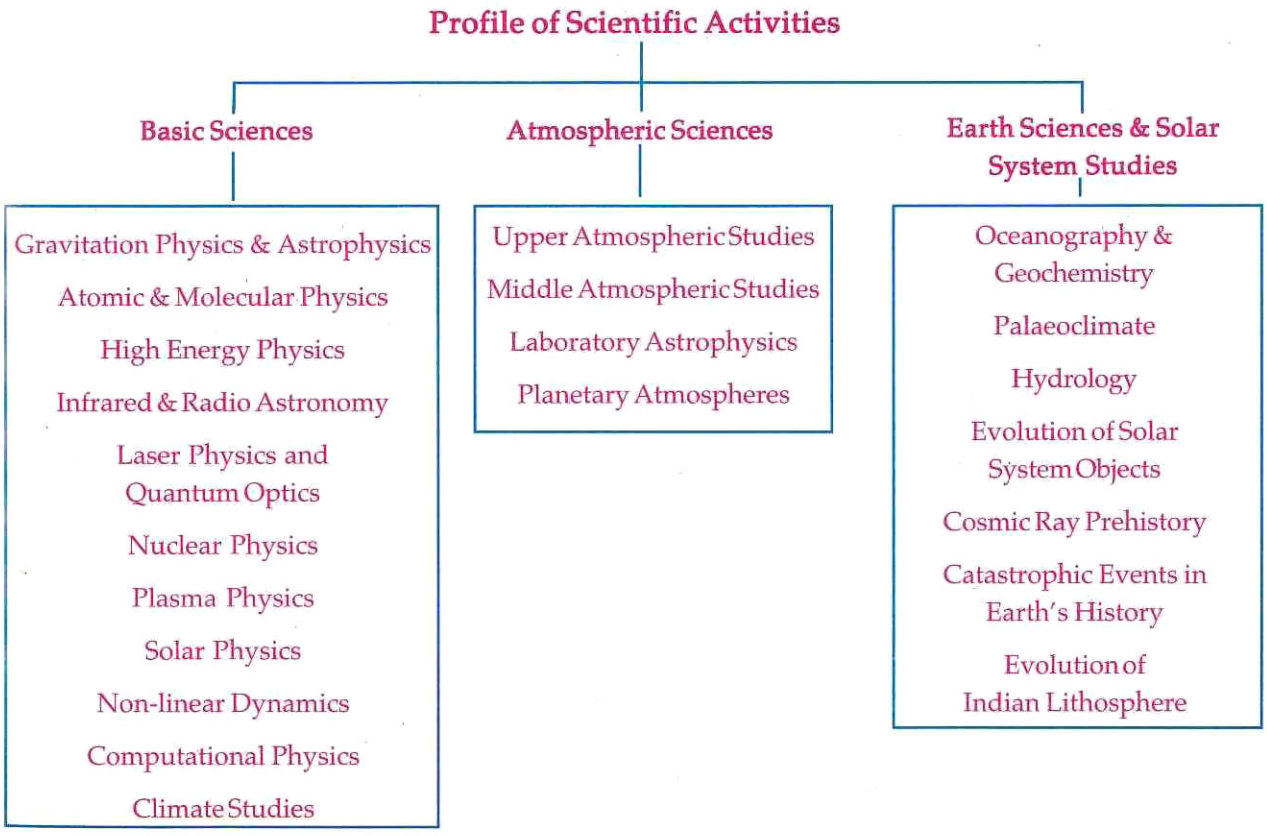
Some of the important research contributions are summarised.

Astronomy and Astrophysics

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

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

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



norphologies, the peaks are off-centred. It was found that the current star formation rate relative to that in the recent past is maximum away from the centre – the peak occurring in the inner half of kiloparsec.

Near infrared photometry and narrow band imaging of the massive and luminous YSO IRAS 05361+3539 done at Mt. Abu Observatory using the NICMOS 3 array detector, had identified several Class I and Class II sources in the vicinity of this object. Class I and II sources represent two early stages of protostars. Molecular hydrogen outflow/jet was detected from this IRAS source which was identified as a Class I source. A possible variable protostar was also detected from the observations.

Near-infrared spectroscopic monitoring was done with NICMOS 3 array of an eruptive variable star V445 Puppis. The results clearly brought out the deficiency of hydrogen in the star as found out from the absence of recombination lines, indicating that the star is a prototype of a new class of symbiotic binaries in which a companion red giant stripped to its helium layers transfers mass to a white dwarf. This is probably the first detection of a "helium nova".

From spatio-kinematic studies using the Imaging Fabry-Perot Spectrometer, the planetary nebula NGC 4361 was shown for the first time to have quadrupolar flows. This morphology which is very rare could have been a result of precession of the progenitor star.

Lunar Occultation technique has been extended to L (3.5μm) band also in addition to the existing regular K (2.2μm) band observations on late M giants. While lunar occultations give the important stellar radius parameter for M giant stars, infrared spectroscopy with NICMOS 3 is being used to precisely determine their spectral type from the equivalent widths of the CO absorption bands in the region 2.3-2.5μm.

Under the on-going Indo-French collaborative programme, new results on the inner central region of Milky Way Galaxy were obtained on the extinction using the archival 2 MASS and the ISOGAL database.

On the Radio Astronomy front, some selected quasar sources are being studied using the GMRT facility to obtain their brightness distribution in several frequency bands. These sources are rather peculiar having larger inherent sizes than "usual", perhaps due to their internal structure in the interface regions or due to some voids in the intergalactic medium, thus enabling the galaxy to overcome the ram pressure to attain larger sizes.

For the first time, variation of solar coronal rotation with altitude (or differential rotation) was detected using daily measurements of solar flux at eleven radio frequencies in the range of 275-2800 MHz. This work was done in collaboration with the Brazilian solar astronomers. In another collaborative effort with University of Maryland, USA, a radio source was detected at 0.33 GHz that moved during a solar flare at a speed of 26000 km/s. This velocity of the disturbance, by far the largest detected ever, could have been a result of realignment of magnetic fields connecting different portions of an active region.

Some new observation facilities are being planned. Firstly a robotic telescope of size 20 cm is being commissioned that can operate within a minute of a trigger received from Gamma Ray Burst Network. A major facility for submillimeter science and technology programme is being developed.

Solar cycle related changes in the seismic radius of the Sun as well as in the rotation rate of the upper solar convection zone were detected. Local area seismology was employed to find some signatures of strong correlation in velocity and intensity oscillations. The stochastic variation of acoustic power spectra were filtered to find a very small N-S assymmetry in the peak frequency of the solar acoustic spectrum. Chromospheric and photospheric magnetic fields were compared to obtain a model independent geometrical scale for the 3-D structure of solar active regions. The polarisation of the solar corona upto $1.5R_{\odot}$ was mapped to detect patches of the corona with non-tangential polarisation that could be signatures of dense structures situated off the plane of the sky. A study of CMEs associated with strong geomagnetic storms revealed an interesting correlation between initial CME speed, ram pressure of the

resulting IP shock and the strength of the associated geomagnetic storm which can provide a crucial predictive capability for space weather.

Theoretical Physics

In Astrophysics, the study of accretion disk dynamics is continued with particular attention to advection dominated flows around black holes. The analysis of self-similar class of solutions in this regard with a quasi-Newtonian potential, introduced perturbatively demonstrated that the perturbative analysis can give better representation and insight into the parameter space of the numerical global solution which includes boundary layer. In addition, it is shown that GTR effects, by including rotation in the treatment, lead to enhancement of neutrino heating rates in Supernova.

In atomic and molecular physics, formulas of the first Born amplitude in terms of the Jacobi polynomials for certain selected transitions involving circular and near circular states have been obtained.

In high energy physics, some aspects of neutrino physics, collider physics, baryogenesis and strong interaction physics are studied. For obtaining the hierarchy of neutrino masses and mixing angles needed for understanding neutrino oscillations, scenarios involving degenerate neutrinos, models involving R-parity violation in supersymmetric theories and on models formulated in the context of theories in which gravity also propagates in some extra dimensions, are explored. Angular distributions of top decay products at e^+e^- linear colliders have been studied. In muon colliders the scattering process with near shell neutrinos is a dominant process. A theoretical calculation of the dependence of the cross sections for these processes on neutrino masses has been carried out, thereby providing yet another way of studying neutrino masses. In an attempt to explain the observed matter-antimatter asymmetry of the universe, a scenario for creating such an asymmetry during inflation and reheating in the early universe has been proposed and studied. Furthermore, studies have been carried out to relate the observed baryon asymmetry with neutrino masses and other neutrino oscillation parameters. In an attempt to find the relationship between realistic phenomenological models of atomic nuclei and the fundamental theory of strong interactions, namely QCD, the study of QCD sum rules at finite densities is being pursued.

In nuclear Physics, electric quadrupole, magnetic dipole and Gamow-Teller strength sums in vary large shell model spaces are analyzed and using these, established that 'transition strength sums' can be considered as a new 'statistic', able to distinguish between regular and chaotic motion in interacting particle systems with the strength sums in the chaotic domain being described by the embedded random matrix ensembles. In addition, analytical and numerical embedded ensemble studies and nuclear shell model calculations are carried out for the localization length in wavefunctions. Using these, it is seen that for realistic finite interacting many particle systems, in the chaotic domain, wavefunction structure is given by (1+2)-body embedded random matrix ensembles.

Plasma Physics research activities are centered around following two areas :(i) Dusty or complex plasmas and (ii) partially ionized plasmas. It is found that in the presence of highly negatively charged dust grains in the plasma, a new kind of normal mode can be generated in dense dusty plasmas. These waves have dispersion characteristics which are similar to those of the acoustic modes, but the role of the pressure is played by the electrostatic energy of the charged grains. Different aspects of these modes have been studied. It is found that in partially ionized plasmas in certain conditions, Rayleigh-Taylor type of instabilities can be generated. The role of gravity can be played by the friction force between the neutral atoms and ions present in partially ionized conditions.

Nonlinear Dynamics & Computational Physics

In the nonlinear dynamics and computational physics division research on both the classical and quantal aspects has continued. In particular, work on chaos and synchronization and on quantum chaos has been carried out. The study of nonlinear dynamics has given rise to the modern interdisciplinary approach to science and this is reflected in our studies on the application of

chaotic dynamics to communications and in studies on turbulence in edge plasma of a tokomak.

We have studied, in detail, various methods of communication based on the synchronization of two identical classically chaotic systems. It is found that a method which employs active - passive decomposition of the chaotic system is suitable.A method which uses combinations of chaotic systems to generate hyperchaotic transmitted signal which carries information is studied with a view of development of secure communications. A study of tokomak edge turbulence is being made by an analysis of the floating potential fluctuation in the edge plasma of the ADITYA tokomak. This study provides evidence of a Levy process and scaling in the edge plasma.

A study on nonlinear integrable models using algebraic methods has been made for a one - dimensional system with an external time - dependent potential. In the model studied, we derived a new, integrable, nonlinear, area preserving, two dimensional map. Both the classical and quantal dynamics of the model were studied and results show exact one - to - one correspondence. This study sheds light on the relation between dynamics of simple systems and the SU(1,1) algebra. Our studies on a particle trapped in an infinite square well potential and subjected to a external periodic field have continued. We had previously reported that the ratio of two length scales in the problem, namely, the well width and the external field wavelength, plays a crucial role in the classical dynamics of the particle. We have now explored the role of this ratio in controlling localization properties of the chaotic quantum eigenfunctions of the system.

Quantum information processing is a subject which is currently attracting much interest world wide. We have been exploring the relationship between the uniquely quantum attribute, namely, entanglement, which measures the non - seperability of states and quantum chaos. Quantum entanglement is considered as a resource for quantum information processing including quantum computing. We have shown that entanglement can be a useful characterization of quantum chaos in models such as, higher dimensional symplectic maps and coupled oscillator systems.

Laser Physics & Quantum Optics

During the last year, we have obtained Wigner functions for various light beams, explained how one light beam guides another and how light propagation can be changed from subluminal to superluminal. We have shown how anisotropy of vacuum brings about quantum inteference and how vacuum-induced potential affects the passage of cold atoms through a cavity. We have presented schemes for improving the fidelity of quantum cloning, generating optical vortices inside a waveguide and realizing optical analog of Bloch oscillations in trapped ions.

The Wigner distribution function is a powerful tool for describing light beams. The Wigner function for Hermite- Gaussian (HG) modes has been known in a compact form for many years. But for Laguerre-Gaussian (LG) modes the Wigner function has been obtained only recently and involves a complicated four-fold summation. It has now been possible to obtain the Wigner function for LG modes in a form as compact as the one for HG modes. We have also derived the linear transform that reconstructs the four-dimensional Wigner function of a rotationally symmetric two-dimensional beam from the Wigner function of its one-dimensional sample along a diagonal.

In a recent experiment, waveguiding effect was electromagnetically induced in a rubidium vapor cell so that one optical beam essentially guides another. We present a theoretical model that fully explains this remarkable phenomenon.

We demonstrate how the anisotropy of the vacuum of the electromagnetic field can lead to quantum interferences among the decay channels of close lying states. We also show that radiative coupling between two multilevel atoms having near-degenerate states can produce new interfering effects in spontaneous emission. We have also shown that these quantum interferences are consistent with thermodynamic equilibrium.

We have shown that the group velocity of a weak electromagnetic pulse propagating through a Λ-system can be changed from subluminal to superluminal in a controlled way by the use of additional electromagnetic fields. We have also discovered a matter-wave analogue of superluminal light propagation in the passage of ultra-cold atoms through a suitably designed cavity.

The fidelity of quantum cloning is very often limited by the accompanying unwanted transitions. We show that the fidelity can be improved by using a coherent field to cycle away these unwanted transitions.

It is well known that optical vortices can be produced in free space. We show that they can also be produced *inside* multimode step-index waveguides by using suitable combinations of waveguide modes. A prescription is also given for generating shape-preserving vortex arrays.

We have discovered an optical analog of Bloch oscillations realized in Fock space and proposed a feasible scheme for inducing Bloch oscillations in trapped ions.

Planetary Atmospheres and Aeronomy

Planetary Atmospheres and Aeronomy Division is involved in the understanding of physical and chemical processes taking place in the atmosphere and ionosphere of earth and other planets. The tools which are used for such studies include ground based optical and radio experiments, balloon, and rocket-borne experiments and theoretical modelling.

Minor constituents of the atmosphere are very important means to monitor and understand the atmospheric pollution. PRL participated in a ship cruise in the Bay of Bengal region from February, 18 to March 22, 2001 to measure surface ozone, NO and CO along with solar radiation and meteorological parameters. These ship borne measurements were supported by land-based measurements of surface ozone from Balasore and Gadanki, near Tirupati.

In the area of aerosols and radiation, an experiment was conducted from Maitri, Antarctica to characterize aerosols and estimate the aerosol radiative forcing as part of the 20th Indian Antarctic expedition. Preliminary results indicate that though the aerosols exhibit characteristics of a pristine region, large day to day variation has been observed in the columnar ozone and water vapor concentrations caused mainly due to changes in atmospheric dynamics. Compared to antarctic pristine site, aerosol content over Bay of Bengal region was found to be about ten times higher.

A high altitude balloon experiment was conducted from Hyderabad using the PRL's sun-tracking photometer system. The data from the experiment is being used to estimate the increase in the background aerosol content at the stratospheric altitudes.

Multi-wavelength all sky optical imaging of ionospheric plasma depletions conducted from Kavalur, India has yielded some new results. Very large areas (1000 km x 1000 km or more) of enhanced airglow intensity (up to a factor of 5) or brightness patterns were detected for the first time in 777.4 nm images. These brightness patterns initially appear in a small area but encompass the entire field of view in a few hours. Another interesting result was the observation of unusually slowly drifting bubbles, wherein the eastward drift velocities became very low and at times the depletions did not show any movement at all. These sluggish depletions were found to be a result of strong magnetic disturbance. These unusual changes in the drift velocity of the depletions have been explained in terms of the penetration of disturbance electric fields from high latitude to low latitude in the earlier part of the night and in the later part of the night, due to combined effect of changes in both electric fields and neutral winds.

During the year two new initiatives were taken in the area of ionospheric physics. The first one was the ISTEP III campaign on Sporadic E, wherein, rapid ionospheric soundings were made from Ahmedabad during June-July, 2000. The other initiative was the Coherent Beacon Experiment (CRABEX), which is proposed by the Space Physics Laboratory (SPL) of VSSC, Trivandrum in collaboration with PRL and Andhra University. The experiment consists of the transmission of coherent radio beacons at 150 and 400 MHz and the

lower side band modulations at 149 and 399 MHz from Indian satellite GSAT-2. A chain of twelve receivers will be set up at different institutions and universities in India. PRL is one of the three nodal centres for operation of the chain and will be responsible for the management of four stations.

Earth Sciences and Solar System Studies

The programmes of the Earth Sciences and Solar System Division focus on the processes contributing to the evolution of the planet Earth and its various reservoirs (mantle, lithosphere, hydrosphere and atmosphere) and the origin and early evolution of the Sun and other solar system objects such as the Moon, Mars, asteroids and comets. The basic approach is to apply concepts and methods of physics and chemistry to understand processes related to the evolution of these objects and their time scales. These studies rely on the use of chemical, isotopic and optical signatures contained in the planetary samples, the detection of which requires the use of sophisticated instrumentation and analytical expertise in which the group has the requisite specialization.

The strong influence of solar activity on Indian monsoon was demonstrated through a multi-proxy, decadal time resolution study of a sediment core from the north-eastern Arabian Sea that covered the last ~1200 years deposition. The proxy records show that the intensity of the biological productivity in the Arabian Sea and river discharge decreased during periods of solar minima. Periodicities of 200 ± 20, 100 ± 15 and 60 ± 10 years observed in the proxy records coincide with those known for solar cycles and instrumental rainfall data of the Indian monsoon. Evidence for the presence of a coupled atmospheric forcing for the Indian and East African monsoon on centennial time scale is also seen.

Sabarmati river in Gujarat flows in a N-S direction in contrast to the NE-SW slope of the region. It has been shown that this change in direction occurred due to tectonic activity in this region sometime between 12 and 4.5 ka before present. The river has been cutting down the old sediments due to increased fluvial activity in response to enhanced south-west monsoon during this period.

Non-mass dependent oxygen isotopic fractionation has been determined as a function of ambient pressure in ozone formed by photolysis of oxygen by UV light. The ozone is highly enriched in both ^{17}O and ^{18}O and the enrichment increases with decrease of oxygen pressure from 400 torr attaining a peak at about 15 torr pressure. These data will be useful in putting constraints on the various theories put forth to explain the anomalous isotopic enrichment in ozone in the stratosphere and also in the laboratory.

Analysis of Sr concentration and Sr isotopic ratio in the Yamuna river system along with a few selected cations and anions shows that two end members regulate the Sr budget of this system. One comes from weathering of high $^{87}Sr/^{86}Sr$ ratio low Sr content silicate rocks and the other from low ratio and high Sr content carbonate, sulphate, phosphorite rocks. The contribution of Himalayan weathering to the Sr budget of oceans can be further constrained with these data.

Oxygen isotope records in early solar system solids suggest the presence of a large reservoir of ^{16}O-rich component in the solar nebula that did not get significantly depleted over the formation duration of these refractory solids. This is unlike the case for the reservoirs of other anomalous stable and radiogenic isotopes (e.g. ^{48}Ca, $^{49,50}Ti$, ^{26}Al, ^{41}Ca) whose records in these objects suggest that these reservoirs got depleted due to removal and/or mixing during the same time interval. Although a stellar origin for the ^{16}O-rich component in the early solar system is generally favoured, the possibility of a local (solar system) origin that can maintain the ^{16}O-rich reservoir over an extended duration cannot be ruled out.

An extensive study of boron isotopic composition in different types of chondrules from several primitive meteorites did not reveal large magnitude anomalies in $^{11}B/^{10}B$ ratio. Our results are at variance with an earlier report and cast doubt on the suggested presence of an anomalous boron component in the early solar system generated by low-energy particle irradiation of the

proto-solar cloud prior to its collapse.

Studies of cosmic ray produced records in the Fermo meteorite revealed the presence of noble gases produced by interactions of thermal neutrons as well as neutrons of solar origin. These observations cannot be explained in terms of conventional cosmic ray exposure of the sample in interplanetary space and suggest that the analyzed sample had a short (~10^4 year) duration surface exposure and a long (>10Ma) duration deep-seated shielded exposure on its parent asteroid prior to its ejection into interplanetary space. Our results provide a very robust evidence for parent body irradiation of meteorite sample.

^{40}Ar-^{39}Ar ages of ~86 Ma for the St.Mary's Islands volcanics match those of the Kerala dykes as well as the age for the Madagascar flood basalt province and suggest that these volcanics and dykes represent magmatic activity associated with the breakup of Greater India (India plus Seychelles) and Madagascar, that took place in the Upper Cretaceous at ~88 Ma.

Noble gas isotopes ^{21}Ne and ^{22}Ne can be produced by (α,n) reactions with target elements oxygen and fluorine, respectively. In U-Th-rich minerals like apatite, which is also enriched in F, nucleogenic neon isotopes could serve as potential chronological tool. This approach has been successfully applied to obtain ages of apatites from a carbonatite sample. The age of 2180 Ma for the analysed sample is consistent with its U-^{136}Xe age of 2150 Ma.

Technical Developments

Laser-probe Mass-spectrometer

The setting up of the laser probe noble gas mass spectrometry has been successfully completed. A Nd-YAG laser with 16W power at 1064 nm (CW) and about 3W power at 532 nm has been used for heating sub-milligram samples for gas extraction. An all metal ultra high vacuum gas extraction system, assembled in-house, has been integrated with the mass spectrometer. The new extraction system gives system blanks for noble gases that are orders of magnitude lower than the glass extraction system coupled with conventional resistance/induction heating. Test runs with meteorite samples show that isotopic analysis of He, Ne and Ar is feasible in samples of about 10μg. This development will allow us to address new problems in planetary sciences that could not be addressed earlier due to sample size constraints.

Accelerator Mass Spectrometer (AMS) Facility

Through concerted efforts of PRL, IOP (Bhubaneswar) and NGRI scientists and funding from several Govt. departments, viz. DOS, DAE, DST and CSIR, the augmentation of the 3 MV pelletron accelerator at IOP, Bhubaneswar is now complete and it is currently undergoing trials for ^{14}C measurements. Since AMS ^{14}C dating needs samples in the form of graphite (~1 mg), two graphitization systems have been set up in PRL. Several graphite samples have been made and some of these have been sent to the AMS laboratories in Arizona and Vienna for ^{14}C measurements. The measurements revealed that PRL samples give excellent ^{12}C currents (an essential requisite to get good signals of ^{14}C) and the standard and sample results are in excellent agreement with the expected/measured values. Some of these samples are currently being measured in IOP. The ^{14}C dating using AMS is expected to be functional by the end of 2001.

Ion-probe Upgradation

The secondary ion mass spectrometer (ion-probe) was augmented by acquiring a SUN workstation and associated softwares for instrument operation. This replaces the earlier PDP-11/53 operating system. The response time for hardware-software interfaces as well as instrument operation protocols have become much better with the SUN system. Necessary data analysis softwares compatible with the new operating system have been developed.

Extraction System for Carbon Isotope Studies

A vacuum extraction line has been set up in PRL to convert methane to CO_2 and water by passing air over hot platinum catalyst (750°C). The CO_2 is then purified for measurement of carbon isotopic ratio using

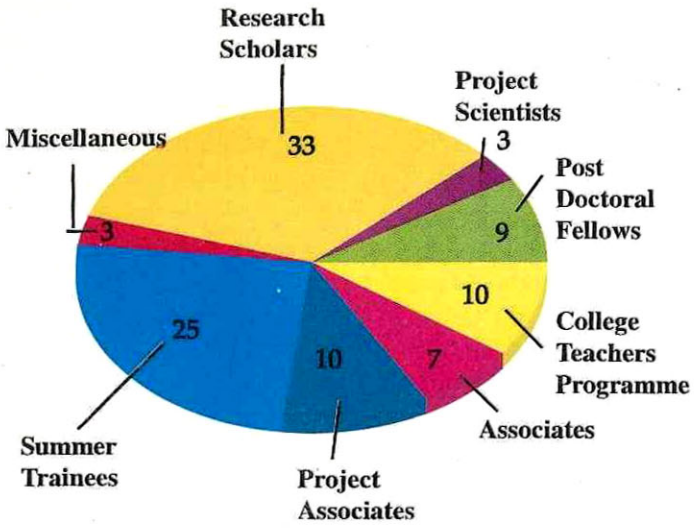


Fig. 1 Doctoral, Post Doctoral and other Programmes

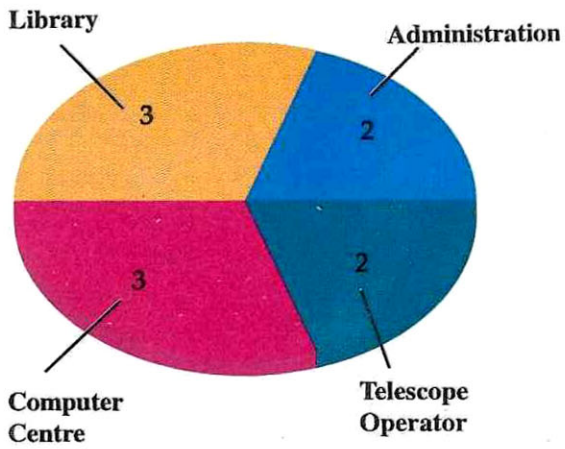


Fig. 3 Apprentice Programme at PRL

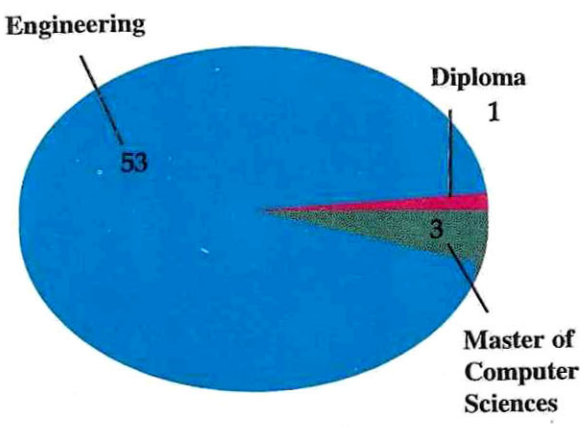


Fig. 2 Projects for Engineering and Diploma Students

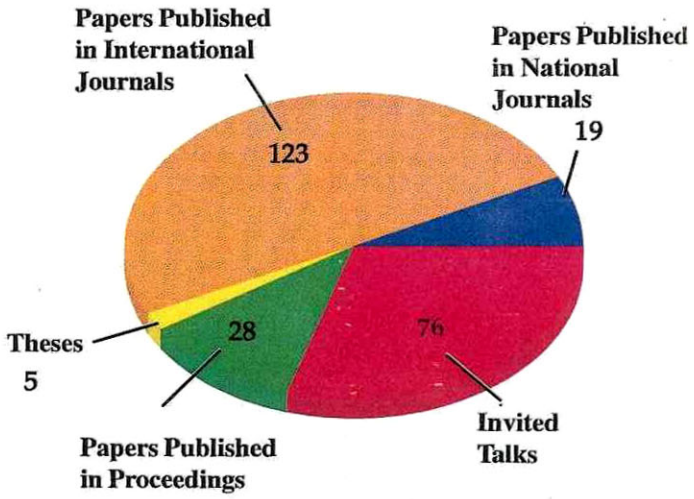


Fig. 4 Scientific Output of PRL

the GEO 20-20 mass spectrometer. Experiments to determine conversion yield and calibration of the isotopic ratio are in progress.

Computer

The Computer Centre at PRL has today a workstation cluster consisting of five IBM RS6000/580 machines and HP9000/735 machine connected on a high speed fibre optic network. In addition, there are many PC's and workstations in all the scientific and administrative areas of the laboratory. Almost all the machines in PRL are connected to the main workstation cluster through a campus wide Ethernet LAN. This enables PRL scientists to have access to the workstations from their desks and laboratories. Furthermore, the PRL system is connected through a VSAT link via the INSAT-II B satellite to the Department of Electronics (ERNET) hub at Bangalore. This allows PRL scientists to access the global Internet and have facilities like *telnet* and *ftp* on their desks. Many software packages like AVS, IDL, IMSL, NAG, Mathematica etc. and public domain packages are also available.

Infra-structural Facilities Available

Computer Centre, Electronics Laboratory,

Scanning Electron Microscope,

Liquid Nitrogen Plant, Glass Blowing Facility,

C-14 Dating Laboratory

Research Opportunities

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

Training Opportunities

PRL provides summer training programme to students doing their Master's degree in Physics to acquaint them with the research programmes and opportunities available at PRL. PRL provides project training in computer science and application to post-graduate students. It also offers training in electronics and computer engineering to engineering and diploma students (**Fig. 2**)

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

Research and other Scientific Details

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

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

Conferences / Symposia Convened

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

1. Symposium on Space Science Technology and Applications, October 24, 2000, **Profs. Harish Chandra & A. C. Das - Co-Conveners.**

2. International Conference on Perspectives in Theoretical Physics, January 8-12, 2001, **Profs. V. B. Sheorey & A. Joshipura - Conveners.**

3. Workshop-cum-Training Course on Meteorite, Asteroids and Planets, February 26-March 2, 2001, **Drs.S.V.S. Murty & Kanchan Pande-Conveners.**

Distinguished Visitors at PRL

The Parliamentary Standing Committee on Science and Technology, Environment and Forests comprising of 14 MPs from both Rajya Sabha and Lok Sabha under the Chairmanship of Shri C. Ramachandriah and five Officers of their Secretariat visited the laboratory, on September 25, 2000 as a part of the on-the-spot study visit of the institutions under the administrative control of the Department of Space (DOS), Bangalore. The activities of the laboratory were presented to the visitors.

Prof. V. Radhakrishnan, Emeritus Professor and former Director of Raman Research Institute, Bangalore delivered the sixteenth **Prof. K.R. Ramanathan Memorial Lecture** entitled *Astronomy's Devices.*

Seminars and Colloquia Held

The laboratory has an extensive seminar and colloquium programme. Reputed scientists, both from national and international institutions were invited to give seminars and colloquia. In addition, the laboratory organised popular lectures by internationally renowned

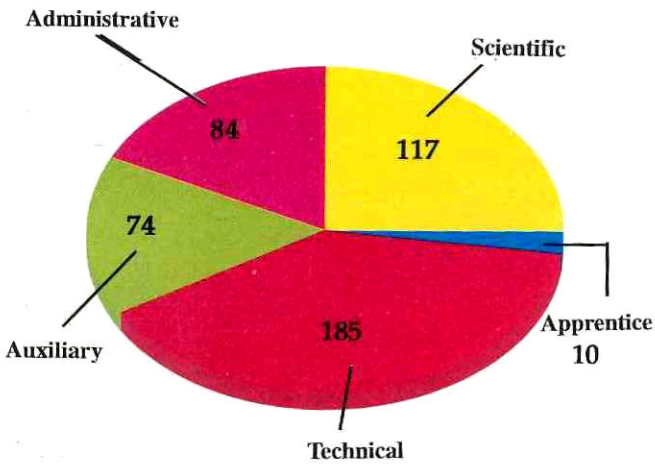


Fig.5 Staff Structure of PRL

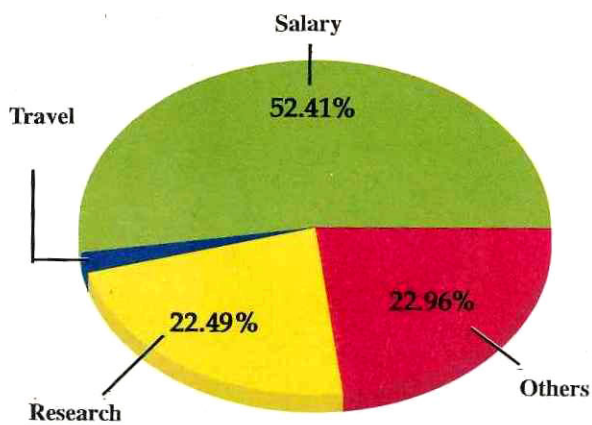


Fig.6 Budget of PRL

scientists. The following gives an idea of the seminars and colloquia including popular lectures held at PRL:

Seminars held	94
Colloquia including public lectures held	45

About 60% of seminars and colloquia were delivered by visitors from within and outside the country.

Administrative Support

Behind the scientific achievements of PRL is the able and efficient support given by the administrative and the technical staff. The administrative section of our laboratory continues to play a pivotal role in providing an excellent management support to carry out our scientific activities. In addition, it also provides management support to the Solar Observatory at Udaipur and the Infrared Observatory at Mt. Abu. The budget and staff structure of PRL are shown in **Figs. 5 and 6**.

Miscellaneous

Physical Research Laboratory honoured seven distinguished scientists at a glittering function on the occasion of the **Vikram Jayanti**. **Dr. S. K. Joshi**, former Director General of the Council of Scientific and Industrial Research graced the celebrations and gave away the **Hari Om Ashram Prerit Vikram Sarabhai Research Awards** and the **PRL Awards**. Five distinguished scientists received the Hari Om Awards and two received the PRL Awards. The Hari Om Awards were instituted on August 12,1974 in honour of Dr. Vikram Sarabhai, founder of Physical Research Laboratory by the Hari Om Ashram, Nadiad. The PRL Award has been instituted in 1997 from the Aruna Lal Endowment Fund established by Prof. D. Lal, Honorary Fellow and former Director of PRL. All the awards consist of a medal and a cash prize of Rs.25,000/-. The scientists who received the **Hari Om Awards** are: **Amitabh Mukerjee** (IIT, Kanpur) received the award for Electronics, Informatics, Telematics and Automation; **H. M. Antia** (TIFR, Mumbai) and **Varun Sahni** (IUCAA, Pune) for Space Sciences; **V. K. Dadhwal** (SAC, Ahmedabad) for Space Applications; **K. Sivan** (VSSC, Thiruvananthapuram) for Systems Analysis or Management. The recipients of the **PRL Award** are **Anil Kumar** (NGRI, Hyderabad) and **Biswajit Mishra** (IIT, Kharagpur).

The laboratory announced the **Hari Om Ashram Prerit Senior Scientist Award** for the year 2000 to the eminent scientist Prof. C. N. R. Rao, Linus Pauling Research Professor at the Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore and former Director of the Indian Institute of Science, Bangalore. The Senior Scientist Award has been instituted in 1998 by the Physical Research Laboratory, with the funds donated by the Hari Om Ashram Trust, Nadiad, to commemorate the birth centenary of Pujya Shri Mota, Founder of the Hari Om Ashram. The award, being given biennially, carries an amount of Rs. 1 lakh and a citation and is made to an Indian scientist (or scientists)

above the age of 45 years for outstanding contributions in science and technology.

As a part of implementation and progressive use of Hindi in PRL, the Hindi Week was celebrated at PRL from September 11 - 17, 2000. The highlights of the celebrations included word quiz, essay, elocution, Hamara Karya, self written poetry competitions and Antakshari. The special attraction of this years celebration was a lecture by **Acharya Raghunath Bhatt**, Chairman of Gujarat Rastrabhasha Prachar Samiti, Ahmedabad who the gave opening lecture.

To impart traning to work in Hindi a two days Hindi Workshop was held during 8-9 June, 2000. Eight Techers were arranged in this workshop on various topics. Around eleven staff members participated in this workshop.

Two All India Eassy Writing and noting & drafting Competitions were held in PRL, Deptt. of Space and Kendriya Sachivalaya Parishad organised one each. Shri Y.M.Trivedi, Head, P&GA has won the IIIrd Prize at All India Level and Shri M.G. Acharya and Shri Vachaspati Pandya won the prize at Ahmedabad Centre level organised by the Kendriya Sachivalaya Parishad.

PRL was awarded with the **Vishesh Prashasti Patra** by Town Official Language Implementation Committee, Ahmedabad for using Hindi in Official and Scientific Activities and for also organising the National level Conference on Hindi and Internet in New Millennium.

The Hindi section also participated in the Rajbhasha Sammelan organised by Small Industries Service Institute, Ahmedabad. The Hindi Officer delivered lectures in Hindi workshops held by different institutes like SAC, SISI, NTC, Door-Darshan and Aakashvani on different topics.

Awards and Honours

1. **Prof. U. R. Rao** has been awarded the
   - i. *Nadoja Award* from Kannada University, Hampi.
   - ii. *Eduard Dolezal Award* of ISPRS.
   - iii. *D. Litt.* (Honoris Causa) by Kannada University, Hampi.
2. **Dr. K. Kasturirangan** has been awarded the
   - i. *M. N. Saha Birth Centenary Award* by the 87th Indian Science Congress.
   - ii. *Aryabhatta Medal Award 2000* conferred by Indian National Science Academy.
   - iii. *P. S. John Endowment Award* conferred by the Ernakulum Press Club, Cochin.
   - iv. *The Degree of Doctor of Sciences* (Honoris Causa) by Indian Institute of Technology, Bombay.
   - v. *The Degree of Doctor of Sciences* (Honoris Causa) by Chatrapati Shahu Ji Maharaj University, Kanpur.
3. **Prof. G. S. Agarwal** has been :
   - i. invited to be a *Topical Editor* for the category of *Quantum Optics, Encyclopedia of Optical Engineering (EOE)*, Mercel Dekker, NY.
   - ii. appointed for a two-year term on the *Max-Born Award Committee* of the Optical Society of America.
4. **Prof. S. Krishnaswami** has been
   - i. elected a *Fellow of the Third World Academy of Sciences, Trieste, Italy.*
   - ii. nominated to the *Evaluation Team of GESAMP (Joint Group of Experts on Scientific Aspects of Marine Environmental Protection, sponsored by UN Agencies).*
   - iii. invited to be an *Associate Editor for Geochim Cosmochim Acta.*
5. **Prof. J.N. Goswami** has been elected a *Fellow of the International Meteoritical Society.*
6. **Dr. R. Ramesh** has been elected
   - i *Fellow, Indian National Science Academy, New Delhi.*
   - ii. *Fellow, Indian Academy of Sciences*, Bangalore.
   - iii. *Member, Scientific Committee on Oceanic Research Working Group 117* on *Millennial Scale Climatic Variability in the Past.*
7. **Dr. Shyam Lal** has been elected
   - i. *Fellow, Indian Academy of Sciences*, Bangalore.
   - ii. *Member of the International Ozone Commission.*
8. **Prof. P. Venkatakrishnan** was nominated as *Member of Organizing Committees of Commissions 10 and 12 of the International Astronomical Union.*
9. **Dr. S. P. Gupta** was *Deputy Scientific Organiser* of Lightning Middle Atmosphere Inter action Session in *33rd COSPAR Scientific Assembly, Warsaw, Poland.*
10. **Prof. S.K. Bhattacharya** has been elected as *Member of the National Co-ordination Committee on Isotope Hydrology (NCCIH).*
11. **Dr. M.M. Sarin** has been elected as *Member of International SCOR Working Group 116 on Sediment Trap and ^{234}Th Methods for Carbon Export Flux Determination.*
12. **Dr. Debi Prasad Choudhary**, won a *Prize in e-communication* organised by Burleigh Instruments, Inc., New York, USA.

13. The paper *Permian-Triassic transitional environment in Spiti Valley, Himalaya, India* by **Shukla A.D., Bhandari N. and Shukla P.N.**, presented at the Symposium on Catastrophic Events and Mass Extinctions: Impact and beyond, held at Vienna during July 9-12, 2000, received the *Best Paper Award for non-European countries.*

14. The paper *Ion probe studies of trace element abundances in early solar system objects* by **Marhas K.K. and Goswami J.N.**, received the *Best Paper Presentation Award* at the 9th ISMAS Workshop on Mass-spectrometary held at Goa, in December 12-16, 2000.

15. The paper *Variations in seismic radius of the Sun* by **S.C. Tripathy, Kiran Jain, A. Bhatnagar and B. Kumar** has been awarded the *Best Paper* Prize in *the Sun and the Solar Physics* section at the XXth Meeting of the Astronomical Society of India, Gorakhpur, 15-18 November, 2000.

16. The paper *High voltage bi-polar switching power supply for solar vector magnetograph* by **Sudhir K. Gupta, Debi Prasad Choudhary, B. Ravindra** has been awarded the *Best Paper* Prize in the *Instrumentation Section* at the XXth Meeting of the Astronomical Society of India, Gorakhpur, 15-18 November, 2000.

Papers Published in Journals in 2000 -01

Review Papers

Astronomy and Astrophysics

1. Ambastha A., "Digital Imaging Techniques for Solar Magnetic and Velocity Fields", in *Automated Data Analysis in Astronomy*, Eds. R. Gupta, H.P. Singh and C.A.L. Bailer-Jones, Narosa Publ. House, N. Delhi, pp. 177-188 (2000).

Earth Sciences and Solar System Studies

2. J. N. Goswami and H.A.T. Vanhala , "Extinct Radionuclides and the Origin of the Solar System", *Protostars and Planets IV*, ed. V. Mannings, S. Russell, and A. Boss (Tucson: Univ. Arizona Press), 965-996 (2000)

3. J. N. Goswami, "Chronology of Early Solar System Events: Dating with Short-lived Nuclides", *The Origin of Chemical Elements in the Solar System*, Ed. O. Manuel, (New York, Plenum Publishing) pp.407-430 (2000).

4. R. Ramesh, "Paleoclimate" in: *Significant Contributions to Geoscience Research in India during the Nineties*, ed. M.S. Srinivasan, Indian National Science Academy, New Delhi, pp.87-94. (2000)

5. B.L.K. Somayajulu and M. S. Srinivasan, "Paleoceanography" in *Significant Contributions to Geoscience Research in India duirng the Ninetees* (Ed. Srinivasan, M.S.), INSA, New Delhi, pp.77-85 (2000).

6. A. K. Singhvi, "Luminescence Dating in Earth Sciences: An Appraisal", *Soc. Brasileira de Pesquisadores Nikkeis, SBPN*, **4**, 1-59, (2000).

7. A. K.Singhvi, A. Bluszcz, M.D. Bateman and M. Someshwar Rao, "Thermoluminescence and Optically Stimulated Luminescence Dating of Loess-Palaeosol Sequences, - Methodological Aspects and Paleoclimatic Implications", *Earth Sci. Revs.*, **54**, 193-221, 2001

Papers Published

Astronomy and Astrophysics

8. B. G. Anandarao, M. S. Nandakumar, N. S Jog, and R. T. Patel, "NIFS : A Near-Infrared Imaging Fabry-Perot Spectrometer", *Bull. Astr. Soc. India*, **28**, 687-695 (2000).

9. Anandmayee Tej and T. Chandrasekhar, "Angular Diameter and Effective Temperature of a Sample of 15 M Giants at 2.2microns from Lunar Occultation Observations", *Mon. Not. R. Astr. Soc.*, **317**, 687-696 (2000).

10. K. S. Baliyan, and U. C. Joshi, "Photoionization Cross-sections for the FeXVII Ion", *Bull. Astr. Soc. India*, **28**, 311 (2000).

11. D. P. K. Banerjee, S. D. Rawat and P. Janardhan, "H_α Observations of Be Stars", *A&A Suppl.*, **147**, 229-242 (2000).

12. M. K. Bird, P. Janardhan, T. L. Wilson, W. Huchtmeier, P. Gensheimer, and C. Lemme, "K-Band Detection of Ammonia and (Possibly) Water in Comet Hale-Bopp", *Earth Moon and Planets*, **78**, 21-28 (1999).

13. M. J. Burgdorf, M. Cohen, S. D. Price, S. Ott, M. P. Egan, T. de Graauw, R. F. Shipman, S. Ganesh, C. Alard and F. Schuller, "A Survey of Selected Areas in the Galactic Plane with ISOCAM", *A & A.*, **360,** 111 (2000).

14. A. Chakraborty, D. K. Ojha, B. G. Anandarao and T. N. Rengarajan, "Massive and Luminous YSO IRAS 05361+3539 and its Environment : A Study of Star Formation in the Parent Cloud-I", *A & A*, **364**, 683-688 (2000).

15. T. Chandrasekhar, and Soumen Mondal, "Fine Structures in the Inner Dust Shell of IRC + 10216 from Lunar Occultation Observations at 2.2 microns", *Mon. Not. R. Astron. Soc.*, **322**, 356-360 (2001).

16. A. I. Efimov, V. K. Rudash, M. K. Bird, P. Janardhan, M. Patzölt, J. Karl, P. Edenhofer, and R. Wohlmuth, "Anisotropic Structure of the Solar Wind in its Region of Acceleration", *Advances in Space Res.*, **26**, 785-788 (2000).

17. A.C. Gupta, A. Subramaniam, R. Sagar and W. K. Griffiths, , "A Complete Photometric Study of the Open Cluster NGC 7790 Containing Cepheid Variables", *A & A Suppl.*, **145,** 365 (2000).

18. Hari Om Vats, J. R. Cecatto, M. Mehta, H. S. Sawant, and J. A. F. C. Neri, "Discovery of Variation in Solar Coronal Rotation with Altitude", *Ap. J. Lett.*, **548**, 87-89 (2001).

19. P. Hennebelle, M. Pirault, D. Teyssier, and S. Ganesh, "Infrared Dark Clouds from the ISOGAL Survey : Con-

straints on the Interstellar Extinction Curve", *A & A.*, **365**, 598 (2001).

20. U. C. Joshi, K. S. Baliyan, S. Ganesh, M.R. Deshpande, S. Bhattacharya, R. K. Kaul, C. L. Kaul, and C. L. Bhat, "Coordinated TeV Gamma-ray and Optical Polarimetric Study of BL Lac Object Mrk 501", *Bull. Astr. Soc. India*, **28**, 409 (2000).

21. Man Mohan, R. Kundliya and K. S. Baliyan, "Photoionization of the Ground State of NiXIX in the Relativistic Breit Pauli Approximation", *Phys. Scr.*, **62**, 207 (2000).

22. P. J. Moran, S. Ananthakrishnan, V. Balasubramanian, A. R. Breen, A. Canals, R. A. Fallows, P. Janardhan, M. Tokumaru and P. J. S. Williams, "Observations of Interplanetary Scintillation During the 1998 Whole Sun Month: A Comparison between EISCAT, ORT and Nagoya Data", *Annales Geophysica*, **18**, 1003-1008 (2000).

23. C. Muthu, B. G. Anandarao and S. R. Pottasch,"A Spatio-Kinematic Study of the Interaction of the PN NGC 246 with the ISM", *A&A*, **355**, 1098-1102 (2000).

24. D. K. Ojha, A. Omont, , S. Ganesh, G. Simon, and M. Schultheis, "Stellar Sources in the ISOGAL Inner Galactic Bulge Field (l = 0°, b = -1°)", *Journal of Astron. Astrophys.* **21,** 77 (2000).

25. D. K. Ojha, T. Sivarani, M. Parthasarathy, A. Omont, S. Ganesh and G. Simon "Spectroscopic Observations of First ISOGAL Sources", *Bull. Astr. Soc. India*, **28**, 697 (2000).

26. F. M. Pathan, "µC makes Effective Frequency Counter", EDN (U.S.A), November 23, 166 (2000).

27. M. Schultheis, S. Ganesh, I. S. Glass, A. Omont, R. Ortiz, G. Simon, J. Th. van Loon, C. Alard, J. A. D. L. Blommaert, J. Borsenberger, P. Fouqui, and H. J. Habing, "DENIS and ISOGAL Properties of Variable Star Candidates in the Galactic Bulge", *A & A.*, **362**, 215 (2000).

28. A. K. Singal, H. O. Vats, and M. R. Deshpande, "Statistics of Occurrence of Giant Pulses from PSR0950+08",*Bull. Astr. Soc. India*, **28,** 295 (2000).

29. D. B. Vaidya, B. G. Anandarao, J. N. Desai, and R. Gupta, "Porous and Fluffy Grains in the Regions of Anomalous Extinction", *J. Astroph. Astr.*, **21**, 91 (2000).

30. S. M. White, P. Janardhan, and M. R. Kundu, "Radio Detection of a Rapid Disturbance Launched by a Solar Flare", *Ap. J. Lett.*, **533**, L167- L170 (2000).

31. A. Ambastha and S.K.Mathew, "Relationship of Non-potentiality and Flaring: Intercomparison for an M-class Flare", *J. Astrophys. Astr.*, **21**, 271-274 (2000).

32. C. Debi Prasad, "The Photospheric Flow Near the Flare Locations of Active Regions", *J. Astrophys. Astr.*, **21**, 249-250 (2000).

33. Guillaume Aulanier, N. Srivastava, S. F. Martin, "Model Prediction for an Observed Filament", *Astrophys. J.* , **543,** 447-456 (2000).

34. Kiran Jain , S.C. Tripathy and A. Bhatnagar , "Solar Cycle Induced Variations in GONG Frequencies and Splitting Coefficients", *Astrophys. J.*, **542**, 521-527 (2000).

35. S.K. Mathew , and A. Ambastha, "Magnetic Field Gradient and Flare: Study of a Small Flare in NOAA 8038", *Solar Phys.*, **197**, 75-84 (2000).

36. S.K. Mathew, and A. Ambastha, "A Rapidly Evolving Active Region NOAA 8032 observed on April 15th, 1997", *J. Astrophys. Astr.*, **21**, 233-236 (2000).

37. N. Srivastava, R. Schwenn, B. Inhester , S.F. Martin, and Y. Hanaoka, "Factors Related to the Origin of a Gradual CME Associated with an Eruptive Prominence on June 21-22, 1998", *Astrophys. J.* , **534,** 468-481, (2000).

38. K. Sankarasubramanian, G. Srinivasulu,, A.V. Ananth, and P. Venkatakrishnan, "Stokes Polarimetry at the Kodaikanal Tower Tunnel Telescope", *J. Astrophys. Astr.*, **21**, 241-244 (2000).

39. S.C. Tripathy, Kiran Jain and A. Bhatnagar, "Helioseismic Solar Cycle Changes and Splitting Coefficients", *J. Astrophys. Astr.*, **21**, 349-352 (2000).

40. S.C. Tripathy, Brajesh Kumar , Kiran Jain and A. Bhatnagar , "Observation of Hysteresis between So-

lar Activity Indicators and p-mode Frequency Shits for Solar Cycle 22", *J. Astrophys. Astr.*, **21**, 357-360 (2000).

Theoretical Physics

Astrophysics

41. J. R. Bhatt and A. R. Prasanna, "Analysis of Self-Similar Solutions of the Advection Dominated Flows around a Black Hole", *Astron. & Astrophys.*, **361**, p. 781-787 (2000).

42. S. Mohanty and A. R. Prasanna, "General Relativistic Contribution to Polarisation of the Cosmic Microwave Background", *Phys. Rev.*, **D63**, p. 027301 (2001).

High Energy Physics

43. A. S. Joshipura and S. D. Rindani, "Vacuum Solutions of Neutrino Anomalies through Softly Broken U(1) Symmetry,", *European Physical Journal*, **C14**, 85-89 (2000).

44. A. S. Joshipura, and S. D. Rindani, "Phenomenology of Pseudo Dirac Neutrinos", *Physics Letters*, **B494**, 114-123 (2000).

45. A. S. Joshipura, Rishikesh S. Vaidya , and Sudhir K. Vempati, " U(1) Symmetry and R Parity Violation" *Phys. Rev.*, **D62**, 093020-0393024 (2000).

46. R. M. Godbole, S. Pakvasa, S. D. Rindani, , and X. Tata, , "Fermion Dipole Moments in Supersymmetric Models with Explicitly Broken R-Parity", *Physical Review*, **D61**, 113003 (2000).

47. Hiranmaya Mishra and J. C. Parikh,, "Chiral Symmetry Breaking, Color Superconductivity and Quark Matter Phase Diagram : A Variational Approach", *Nucl. Phys.*, **A679** 597-615, (2001).

48. Subhendra Mohanty and U. A. Yajnik "Neutrinos and Astroparticle Physics Working Group Report", *Pramana*, **55** 315-325 (2000).

49. Subhendra Mohanty , "Cosmic Microwave Background Anisotropy Constraints on Relict Neutrinos", *Pramana*, **54** 93-100 (2000).

50. Uma Mahanta and Subhendra Mohanty , "Effects of Nonfactorizable Metric on Neutrino Oscillations Inside Supernova", *Phys. Rev.*, **D62**, 083003 (2000).

51. S. D. Rindani, "Effect of Anomalous W Vertex on Decay-Lepton Distributions in $e^+e^- \to t\bar{t}$ and CP-Violating Asymmetries", *Pramana*, **54**, 791-812 (2000).

52. S. D. Rindani, "Decay-Lepton Angular Distributions in $e^+e^- \to t\bar{t}$ in the Soft-Gluon Approximation", *Physics Letters*, **B503**, 292-300 (2001).

53. H. V. Klapdor-Kleingrothaus, H. Paes, and U. Sarkar, "Effects on New Gravitational Interactions on Neutrinoless Double Beta Decay", *Phys. Lett.*, **B478**, 269 (2000).

54. T. Hambye, E. Ma, and U. Sarkar, "Leptogenesis from R-Parity Non-Conservation", *Phys. Rev.*, **D62**, 015010 (2000).

55. Y. Liu and U. Sarkar, "About the Mixing and CP Violation in Neutrino System", *Comm. Theor. Phys.*, **34**, 289 (2000).

56. U. Sarkar, "Models of Neutrino Masses and Baryogenesis", *Pramana*, **54**, 101 (2000).

57. K. Kang, S. K. Kang, and U. Sarkar, "Lepton Flavor Mixing and Baryogenesis", *Phys. Lett.* **B486**, 391 (2000).

58. T. Hambye, E. Ma, and U. Sarkar, "Leptogenesis from Neutralino Decay with Non-Holomorphic R-Parity Violation", *Nucl. Phys.*, **B590**, 429 (2000).

59. H. V. Klapdor-Kleingrothaus, St. Kolb and U. Sarkar, "Neutrino Majorana Mass and Baryon Number below the Electroweak Symmetry Breaking Scale", *Phys. Lett.*, **B487**, 289 (2000).

60. H. V. Klapdor-Kleingrothaus, H. Paes and U. Sarkar, "Effects of Quantum Space-Time Foam in the Neutrino Sector", *Eur. Phys. Jour.*, **A8**, 577 (2000).

61. H. V. Klapdor-Kleingrothaus, H. Paes and U. Sarkar, "Confronting Dilaton Exchange Gravity from Experiments", *Phys. Lett.*, **B488**, 398 (2000).

62. D. A. Demir, E. Ma, and U. Sarkar, "Neutrino Masses and the Gluino-Axion Model", *J. Phys.*, **G26**, L117 (2000).

63. E. Ma, M. Raidal and U. Sarkar, "Verifiable Model of Neutrino Masses from Large Extra Dimensions", *Phys. Rev. Lett.*, **85**, 3769 (2000).

64. E. Ma, G. Rajasekaran and U. Sarkar, "Light Sterile Neutrinos from Large Extra Dimensions", *Phys. Lett.*, **B495**, 363 (2000).

65. S. Sengupta, P. K. Kaw, and J. C. Parikh, "Transverse Modes and Chaos in Classical SU(2) Yang-Mills Plasma", *Phys. Lett.*, **B498**, 223 (2001).

Nuclear Physics

66. V. K. B. Kota, and R. Sahu, "Theory for Matrix Elements of One-Body Transition Operators in the Quantum Chaotic Domain of Interacting Particle Systems", *Phys. Rev.*, **E62**, 3568-71 (2000).

67. Kinnary Patel , M. S. Desai, V. Potbhare and V. K. B. Kota, "Average-Fluctuations Separation in Energy Levels in Dense Interacting Boson Systems", *Phys. Lett.*, **A275**, 329-337 (2000).

Plasma Physics

68. N. N. Rao, "Electrostatic Modes in Dense Dusty Plasmas with High Fugacity : Numerical Results", *Phys. Plasmas*, **7**, 3214-3226 (2000).

69. N. N. Rao, and F. Verheest, "Electrostatic Dust Modes in Self-Gravitating Dusty Plasmas with High Fugacity", *Phys. Lett.*, **A268**, 390-394 (2000).

70. N. N. Rao, and P. K. Shukla, "Nonlinear Waves in Dense Dusty Plasmas with High Fugacity", *Phys. Plasmas*, **8**, 370-373 (2001).

71. N. N. Rao, L. Stenflo and P. K. Shukla, "Electrostatic Surface Waves in Dense Dusty Plasmas with High Fugacity", *Phys. Plasmas*, **8**, 690-696 (2001).

72. H. Schamel, Nilakshi Das and N. N. Rao,, "Electrostatic Thermal Modes in Dusty Plasmas", *Phys. Plasmas*, **8**, 671-674 (2001).

73. N. N. Rao,, "Electrostatic Waves in Dense Dusty Plasmas with High Fugacity", *Physica Scripta*, **T89**, 176-182 (2001).

74. R. K. Varma, "A Kinetic Description of Low Frequency Longitudinal Waves in a Dusty Plasma including Charge Fluctuations", Phys. Plasmas, **7**, 3505 (2000).

75. R. K. Varma, "Fluid Equations for a Dusty Plasma with Dust Charge and Mass Distribution Interacting with Neutral Dust through Dust Grain Charging and Secondary Emissons", *Phys. Plasmas*, **7**, 3885 (2000).

Nonlinear Dynamics and Computational Physics

76. Biju Thomas, Kasture, S.V. and V. Satyan, "Simulation of Winter and Summer Climates with PRL Atmospheric General Circulation Model", Mausam,**50**, 391-400 (1999).

77. Biju Thomas, Kasture, S.V. and V. Satyan, "Sensitivity of South Asian Summer Monsoon and Tropical Circulations to 1987 and 1988 Sea Surface Temperature Anomalies", ATMOSFERA, **13**, 147-166 (2000).

78. Biju Thomas, Kasture, S.V. and V. Satyan, "Links between Tropical SST Anomalies and Precursory Signals Associated with the Interannual Variability of Asian Summer Monsoon", Meteorol. Atmos. Phys., **75**, 39-49 (2000).

79. N. R. Cerruti, A. Lakshminarayan, J. H. Lefebvre, S. Tomsovic, "Exploring Phase Space Localization of Chaotic Eigenstates via Parameter Variation", Phys. Rev. E., **63,** 016208 (2000).

80. A. Lakshminarayan, N. R. Cerruti, S. Tomsovic, "Phase Space Localization of Chaotic Eigenstates: Violating Ergodicity", Phys. Rev. E., **63**, 016209 (2000).

81. A. Lakshminarayan, "Barnett-Pegg Formalism of Angle Operators, Revivals and Flux Lines" Phys. Rev. A., **62**, 042110 (2000).

82. R. Sankaranarayanan, A. Lakshminarayan, V. B. Sheorey, " Chaos in a Well: Effects of Competing Length Scales", Phys. Lett. A., **279**, 313 (2001).

83. J. N. Bandyopadhyaya, A. Lakshminarayan, V. B. Sheorey, " Algebraic Approach in the Study of Time-Dependent Nonlinear Integrable Systems: Case of the Singular Oscillator", Phys. Rev. A., **63,** 042109(2000).

Laser Physics and Quantum Optics

84. R. Kapoor and G. S. Agarwal,"Theory of Electromegnetically Induced Waveguides", *Phys. Rev. A*,**61**, 053818 (2000).

85. G. Morigi and G. S. Agarwal, "Temperature Variation of Ultra Slow Light in a Cold Gas", *Phys. Rev. A*, **62**, 013801 (2000).

86. G. S. Agarwal and R. Arun, "Resonant Tunneling of Ultracold Atoms through Vacuum Induced Potentials", *Phys. Rev. Lett.*, **84**, 5098-5101 (2000).

87. G. S. Agarwal, "Anisotropic Vacuum Induced Interferences between Decay Channels", *Phys. Rev. Lett.*, **84**, 5500-5503 (2000).

88. R. Arun, G. S. Agarwal, M.O. Scully and H. Walther, "Maser Action in a Bimodal Cavity", *Phys. Rev. A*, **62**, 023809-1-023809-12 (2000).

89. G. S. Agarwal and R. Simon, "Reconstruction of the Wigner Transform of a Rotational Symmetric Two-dimensional Beam from the Wigner Transform of the Beam's One-dimensional Sample", *Optics Letters*, **25**, 1379-1381 (2000).

90. R. Simon and G. S. Agarwal, "Wigner Representation of Laguerre-Gaussian Beams", *Optics Letters*, **25**, 1313-1315 (2000).

91. J. von Zanthier, C. Skornia, G. S. Agarwal and H. Walther, "Quantum Coherence in a Single Ion due to Strong Excitation of a Metastable Transition", *Phys. Rev. A*, **63**, 013816-1-6 (2001).

92. M. O. Scully, G. S. Agarwal, O. Kocharovskaya, V. V. Kozlov and A. B. Matsko, "Mixed Electromagnetically and Self-induced Transparency", *Optics Express*, **8**, 66-75 (2001).

93. G. S. Agarwal and S. Menon, "Quantum Interferences and the Question of Thermodynamic Equilibrium", *Phys. Rev. A*, **63**, 023818-1-8 (2001).

94. G. S. Agarwal, Robert W. Boyd, Elna M. Nagasako and Sean J. Bentley, "Comment on Quantum Interferometric Optical Lithography: Exploiting Diffraction Limit", *Phys. Rev. Lett.*, **86**, 1389 (2001).

95. G. S. Agarwal and J. Banerji, "Off Resonant Pumping for Transition from Continuous to Discrete Spectrum and Quantum Revivals in Systems in Coherent States", *J. Opt. B: Quant. Semiclass. Opt.*, **3**, *S79-S82 (2001).*

96. J. Banerji, "Non-linear Wave Packet Dynamics of Coherent States", Pramana, **56**, 267-280 (2001).

97. P.S. Aithal, P. Premkiran, D. Narayan Rao "Optical Limiting Studies in Photorefractive Pure and Iron Doped BSO Crystal", *J. Nonlinear Optical Physics & Materials*, **9**, 217-225, 2000.

Planetary Atmospheres and Aeronomy

98. Y. B. Acharya, "A Wide Range Linear Electrometer", *Rev. Sci. Inst.*, **71**, 2585-88, (2000).

99. Alok Taori, R. Sridharan, D. Chakrabarty, R. Naryanan and P.V.S. Ramarao, "Coordinated Thermospheric Day-night Airglow and Ionospheric Measurements from Low Latitude - First Results", *Geophys. Res. Lett.* **28**, 1383-1386 (2001).

100. D. K. Chakrabarty , N.C. Shah, K.V. Pandya and S.K. Peshin, "Long-term Trend of Tropopause over New Delhi and Thiruvananthapuram", *Geophys. Res. Lett.*, **27**, 2181-2184 (2000).

101. D. K. Chakrabarty , S.K. Peshin, S.K. Srivastava, N.C. Shah and K.V. Pandya, "Further Evidence of Total Ozone Variation during the Solar Eclipse of 1995", *J. Geophys. Res.* , **106**, 3213-3218 (2001).

102. H. Chandra , H .S .S. Sinha and R. G. Rastogi , "Coordinated Study of Equatorial Electrojet Current from Rocket and Ground Data", *J. Ind. Geophys. Union*, **4**, No.2(a), 23-28 (2000).

103. H. Chandra, Som Sharma, C. V. Devasia , K. S. V. Subbarao, R. Sridharan, J. H. Sastri and J. V. S. V. Rao, "Sporadic-E Associated with Leonid Meteor Shower Event of November 1998, over Low and Equatorial Latitudes", *Ann Geophysics.*, **19**, 59-69 (2001).

104. A. Jayaraman and S. Ramachandran, "In-situ Study of Aerosol Characteristics over the Arabian Sea and Indian Ocean of Relevance to Correction of Satellite Remote Sensed Data", *Adv. Space Res.*, **25 (5)**, 1045 – 1049 (2000).

105. S. Lal , M. Naja and B. H. Subbaraya, "Seasonal Variations in Surface Ozone and its Precursors over an Urban Site in India", *Atmos. Environ.* **34**, 2713-2724, (2000).

106. S. Lal and V. Sheel, "A Study of the Atmospheric Photochemical Loss of N_2O based on Trace Gas Measurements", *Chemosphere - Global Change Sci.*, **2**, 455-463(2000).

107. Lelieveld J., P. J. Crutzen, V. Ramanathan, M.O. Andreae, C.A.M. Brenninkmeijer, T. Campos, G.R. Cass, R.R. Dickerson, H. Fischer, J.A. de Gouw, A. Hansel, A. Jefferson, D. Kley, A.T.J. de Laat, S. Lal, M.G. Lawrence, J.M. Lobert, O.L. Mayol-Bracero, A.P. Mitra, T. Novakov, S.J. Oltmans, K.A. Prather, T. Reiner, H. Rodhe, H.A. Scheeren, D. Sikka and J. Williams, "The Indian Ocean Experiment: Widespread Air Pollution from South and Southeast Asia" Sci., **291**,1031-1036(2001).

108. P. K. Patra , S. Lal, V. Sheel, B. H. Subbaraya, C. Bruehl, R. B. Borchers, and P. Fabian, "Chlorine Partitioning in the Stratosphere Based on In-situ Measurements", *Tellus*, **52B**, 934-946 (2000).

109. S. Ramachandran, V. Ramaswamy, G. L. Stenchikov, and A. Robock, "Radiative Impact of the Mt. Pinatubo Volcanic Eruption: Lower Stratospheric Response", *J.Geophys. Res.*, **105**, 24,409-24,429 (2000).

110. J. H. Sastry, N. Jyothi , V. V. Somayajulu , H. Chandra and C. V. Devasia , "Ionospheric Storm of Early November 1993 in the Indian Equatorial Region", *J Geophys. Res.*, **105**, 18443-18455 (2000).

111. R. Sekar , L. A. Kherani, K. S. Viswanathan, A.K. Patra, P. B. Rao, C. V. Devasia, K. S. V. Subbarao, D. Tiwari and N. Ramachandran, "Preliminary Results on Equatorial Spread-F Irregularities by VHF and HF Radars", *Indian J. Radio Space Phys.*, **29**, 262-271 (2000).

112. H. S. S. Sinha, and Shikha Raizada, "Some New Features of Electric Field Fluctuations Observed over SHAR during Strong Spread F", *Ann. Geophysicae*, **18**, 523-531, 2000.

113. H. S. S. Sinha and Shikha Raizada, "Some New Features of Ionospheric Plasma Depletions over the Indian Zone using All Sky Optical Imaging", *Earth, Planets and Space*, 52, 8,549-559, 2000.

114. V. Sivakumaran, K.P. Subramanian and Vijay Kumar, "Lifetime Measurement of NO_2 at 423-462 nm", *J. Quant. Spectrosc. Radiat. Transfer*, **69**, 513-518 (2001).

115. V. Sivakumaran , K. P. Subramanian and Vijay Kumar, "Lifetime Measurement of NO_2 in the Predissociation Region 399-416 nm", *J. Quant. Spectrosc. Radiat. Transfer*, **69**, 519-524 (2001).

116. V. Sivakumaran , K.P. Subramanian and Vijay Kumar, "Self-quenching and Zero-pressure Lifetime Studies of NO_2 at 465-490, 423-462 and 399-416 nm", *J. Quant. Spectrosc. Radiat. Transfer*, **69**, 525-534 (2001).

117. B. H. Subbarya , A. Jayaraman, K. Krishnamoorthy and M. Mohan, "Atmospheric Aerosol Studies under ISRO's Geosphere Biosphere Programme", *J. Ind. Geophys. Union*, **4**, 77-90 (2000).

Earth Sciences and Solar System Studies

118. S. K. Bhattacharya, J. Savarino, and M .H . Thiemens, "A New Class of Oxygen Isotopic Fractionation in Photodissociation of Carbon Dioxide: Potential Implications for Atmospheres of Mars and Earth", *Geophys. Res. Lett.*, **27**, 1459-1462, 2000.

119. R. Bhusan, B. L. K. Somayajulu, S. Chakraborti and S. Krishnaswami, "Radiocarbon in the Arabian Sea Water Column: CO_2 Exchange Rates and Temporal Variations in Bomb ^{14}C since GEOSECS", *J. Geophys. Res.*, **105**, No.C6, 14273-14282 (2000).

120. V. Courtillot, Y. Gallet, R. Rocchia, G. Feraud, E. Robin, C. Hofmann, N. Bhandari and Z. Ghevariya, "Cosmic Markers, $^{40}Ar/^{39}Ar$ Dating and Paleomagnetism of the KT Sections in the Anjar area of the Deccan Large Igneous Province", *Earth Planet. Sci. Lett.*, **182**, 187-156 (2000).

121. S. Ghosh, N.C. Pant, T. K. Rao, C. Ramamohana, J. B. Ghosh, S. Shome, N. Bhandari, A. D. Shukla and K. M. Suthar, "The Vissannapeta Eucrite", *Meteorit. Planet. Sci.*, **35**, *913-917* (2000).

122. J. N. Goswami, K. K. Marhas, and S. Sahijpal, "Did Solar Energetic Particles Produce the Short-lived Nuclides Present in the Early Solar System?", *Astrophys. J.*, **549**, 1151-1159 (2001).

123. D. Jagadheesha, R.S. Nanjundaiah and R. Ramesh, "Sensitivity of an AGCM to orbital parameters and glacial boundary conditions", *Vayu Mandal*, **29**, 359-363 (2001).

124. D. Jagadheesha and R. Ramesh, "Past Monsoons: A Review of Proxy Data and Modelling", *Mausam*, **52**, 275-284 (2001).

125. N. Juyal, R. Raj, D.M. Maurya, L.S. Chamyal and A.K. Singhvi "Chronology of Late Pleistocene Paleoenvironmental Changes in the Lower Mahi Basin, Western India", *J. Quat. Sci.*, **15(5)**, 501-508, (2000).

126. J. Kailath, T.K. Gundurao, R.P. Dhir, K.S.V. Nambi, V.D. Gogate and A.K. Singhvi, "Electron Spin Resonance Characterization of Calcretes from Thar Desert for dating applications", *Rad. Meas.*, **32**, 371-383, (2000).

127. V.S. Kale, A.K. Singhvi, P.K. Mishra and D. Banerjee, "Sedimentary Record and Luminescence Chronology of Late Holocene Paleofloods in the Luni valley, Thar Desert, Northwest India", *Catena*, **40**, 337-358, (2000).

128. A. Kar, A.K. Singhvi, S.N. Rajaguru, N. Juyal, D. Banerjee, J.V. Thomas and R.P. Dhir, "Reconstruction of Late Quaternary Environment of the Lower Luni plains, Thar Desert, India", *J. Quat. Sci.* **16(1)**, 61-68, (2001).

129. A. S. Khadkikar, L.S. Chamyal and R. Ramesh, "The Character and Genesis of Calcretes in Late Quaternary Sub-humid to Semi-arid Alluvial Deposits, Mainland Gujarat, Western India", *Paleogeog. Paleoclim. Paleoecol.*, **162**, 239-261 (2000).

130. P. Kumar, M. Ebihara and S. K. Bhattacharya, "$^{196}Hg/^{202}Hg$ ratio and Hg Content in Meteorites and Terrestrial Standard Rocks: ARNAA Study", *Geochemical Journal*, **35**, 101-116, (2001).

131. R. Kuhn, T. Trautman, A.K. Singhvi, M.R. Krbetschek, G.A. Wagner and W. Stolz, "A Study of Thermoluminescence Emission Spectra and Optical Stimulation Spectra of Quartz of Different Provenances", *Rad. Meas.*, **32**, 653-657, (2000).

132. R. K. Mohapatra and S. V. S.Murty,"Origin of Air-like Noble Gases in Oceanic Basalts", Geophys. Res. Lett., **27**, 1583-1586, (2000)

133. G. V. Rathiprasad, D. P. Mohapatra, A. M. Punithavelu, B. L. K. Somayajulu and K. Gopalan, "Status of the AMS Project at IOP, Bhubaneshwar", *Nucl. Instrum. Meth. Phys. Res.*, **B172**, 66-69, (2000).

134. J. S. Ray, J. R. Trivedi and A. M. Dayal, "Strontium isotope Systematics of Ambadonger and Sung Vally Carbonatite-Alkaline Complexes, India: Evidence for Liquid Immiscibility, Crustal Contamination and Long-lived Rb/Sr Enriched Mantle Sources", *J. Asian Earth Sci.*, **18**, 585-594, (2000).

135. S. Sahijpal, J. N. Goswami and A. M. Davis, "K, Mg, Ti and Ca Isotopic Compositions and Refractory Trace Element Abundances in Hibonites from CM and CV Meteorites: Implications for Early Solar System Processes", *Geochimica Cosmochimica Acta*, **64**, 1989-2005, (2000).

136. M.M. Sarin, S. Krishnaswami, T.K. Dalai, V. Ramaswamy and V. Ittekkot. "Fluxes of U and Th Series Nuclides in the Bay of Bengal: Results from Time Series Sediment Trap Studies", *Deep-Sea Res.*, **47**, 1961-1985, (2000).

137. B. L. K. Somayajulu, "Submarine Groundwater Discharge (SGD)", *A.P. Acad. Sci.*, **5**, 127-129, (2001).

138. P. Srivastava, N. Juyal, R.J. Wasson and A.K.Singhvi, "Luminescence Chronology of River Adjustment and Incision of Quaternary Sediments in the Alluvial Plain of Sabarmati River, North Gujarat, India", *Geomorphology*, **36**, 217-229, (2001).

139. P. Srivastava, P.K. Mishra, I.B. Singh and A.K. Singhvi, "Luminescence Chronology and Facies Development of Bhur Sands in the Interfluve Region of the Central Gangetic Plain, India". *Current Science*, **78**, 498-503, (2000).

130. G. Srinivasan, G. R. Huss and G. J. Wasserburg, "A Petrographic, Chemical and Isotopic Study of Calcium-aluminum-rich Inclusions and Aluminum-rich Chondrules from the Axtell (CV3) Chondrite", *Meteorit. Planet. Sci.*, **35**, 1333-1354, (2000).

141. J.T. Teller, K.W. Glennie, N. Lancaster and A.K. Singhvi., "Calcareous Dunes of the United Arab Emirates and Noah's Floods: The Post Glacial Flooding of the Persian Gulf", *In Quat. Int.*, **67-71**, 297-308, (2000).

142. M. G. Yadava and R. Ramesh, "Past Rainfall and Trace Element Variations in a Tropical Speleothem from India", *Mausam*, **52**, 307-316, (2001).

Papers Pub. in Proc. of Symposia/Schools in 2000-01

Astronomy and Astrophysics

1. S. Ananthakrishnan, M. Kojima, M. Tokumaru, V. Balasubramanian, P. Janardhan, P. K. Manoharan, and M. Dryer, "Study of Solar Wind Transients Using IPS", *Proc. of Solar Wind 9 Conference*, S.R. Habbal, eds., AIP, New York, pp 321-324 (1999).

2. N. M. Ashok and D. P. K. Banerjee, "The Near IR Spectroscopic Observations of Early Type Be Stars", *ASP Conference Series*, **214**. 468-471, Editors: M.A. Smith, H.F. Henriches & J. Fabregat (2000).

3. N. M. Ashok and D. P. K. Banerjee, "V445 Puppis", *IAU Circular 7559*, 11 Jan. 2001.

4. N. M. Ashok, A. Tej, and D. P. K. Banerjee "V 4643 Sagittarii", *IAU Circular 7599*, 19 March 2001.

5. F. C. R. Fernandes, J. R. Cecatto, J. A. C. F. Neri, C. Faria, A. R. F. Martinon, R. R. Rosa , F. P. V. Mesquita, V. A. Portezani, M. C. Andrade, E. M. B. Alonso, H. O. Vats, and H. S. Sawant, " O Brazilian Solar Spectroscope (BSS), E os Problemas Atuais da Fisica Solar", *Sociedade Astronomica Brasiliera*, **20**, 33 ,(2000).

6. C. Muthu, B. G. Anandarao, and S. R. Pottasch, "A Spatio-Kinematic Study of the Interaction of the PN NGC 246 with the Interstellar Medium", *Proceedings of the Conference on Asymmetric Planetary Nebulae*, Cambridge, Mass, USA (2000).

7. D. K. Ojha, A. Omont, S. Ganesh, G. Simon, and M. Schultheis, "ISOGAL, DENIS and 2MASS Study of the Central Regions of our Galaxy" *IAU Symp.* , Manchester **205**, 111 (2000).

8. A. Ambastha and S.K. Mathew, "A Comparison of Flux Emergence, Cancellation, and Motions in Flaring and Non-Flaring Sites of NOAA 8038 Observed by USO Magnetograph", in Proceedings of *20th International Sacramento Peak Summer Workshop on Advanced Solar Polarimetry - Theory, Observations, and Instrumentation*, Eds. M. Sigwarth, ASP Conf. Series, Vol. **236** (2000).

9. C. Debi Prasad, "Cometary and Solar Observations with Small Telescopes Connected to a Computer Network", in *Seminars of the United Nations Programme on Space Applications*, Tulous, France, ST/SPACE/5, United Nations, New York, pp. 87-92 (2000).

10. Kiran Jain, S. C. Tripathy and A. Bhatnagar , "On Solar Rotation Rate in the Upper Convection Zone", in *Helio- and Asteroseismology at the Dawn of the New Millennium*, Ed. A. Wilson, ESA-SP **464**, 641-644 (2001).

11. Kiran Jain, S.C. Tripathy and A. Bhatnagar,"Temporal Evolution of *f*-mode Frequencies and Radius", in *Helio- and Asteroseismology at the Dawn of the New Millennium*, Ed. A. Wilson, ESA-SP **464**, 95-98 (2001).

Theoretical Physics

Astrophysics

12. A. R. Prasanna and S. Mohanty, "Electromagnetic Wave Propagation in General Space Times with Curvature and /or Torsion", in *The Universe Perspectives and Visions*, Eds. N: Dadhich and A. Khembhavi,Kluwer Pub., p. 277 (2000).

High Energy Physics

13. H. Mishra, "Vacuum Structure in QCD and Correlation Function", in *Proceedings of DAE Nuclear Physics Symposium*, Chandigarh, India, (December, 1999).

Nuclear Physics

14. V. K. B. Kota , "Random Matrix Ensembles and Complete Spectroscopy", in *Nuclear Structure and Dynamics*, edited by A.K. Jain and R.K. Bhowmik (Phoenix Publishing House Pvt Ltd, New Delhi, India, 2000) p. 179-191.

15. V. K. B. Kota and R. Sahu, "Nature of Matrix Elements in the Quantum Chaotic Domian of Interacting Particle Systems", *Proceedings of the National workshop on Non-Linear Dynamical Systems*, edited by V. Srinivasan, A.K. Kapoor and P.K. Panigrahi (Allied Publishers Limited, Hyderabad, India, 2000) p. 42-52.

Plasma Physics

16. N. N. Rao, "Waves in Dusty Plasmas and the Concept of Fugacity", *Proceedings of the International Workshop on Waves in Dusty, Solar and Space Plasmas*, eds. F. Verheest, M. Goosens, M.A. Hellberg, and R. Bharuthram, (AIP Conference Proceedings, **537**, New York, 2000), pp. 13-21.

17. R. Bharuthram, N. N. Rao, and S. R. Pillay, "Non-Ideal Magnetized Dusty Plasma : Self-Similar Solutions",

Proceedings of the International Workshop on Waves in Dusty, Solar and Space Plasmas, eds. F. Verheest, M. Goosens, M.A. Hellberg, and R. Bharuthram, (AIP Conference Proceedings, **537**, New York, 2000), pp. 33-40.

18. S.R. Pillay, N. N. Rao, and R. Bharuthram, "Linear and Nonlinear Dust-Acoustic Waves in Non-Ideal Dusty Plasmas with Grain Charge Fluctuations", *Proceedings of the International Workshop on Waves in Dusty, Solar and Space Plasmas*, eds. F. Verheest, M. Goosens, M.A. Hellberg, and R. Bharuthram, (AIP Conference Proceedings, **537**, New York, 2000), pp. 68-75.

19. A.A. Shaikh, J.R. Bhatt and Rao, N.N., "Dust-Acoustic and Gravity Modes in Barometric Equilibrium", *Proceedings of the International Workshop on Waves in Dusty, Solar and Space Plasmas*, eds. F. Verheest, M. Goosens, M.A. Hellberg, and R. Bharuthram, (AIP Conference Proceedings, **537**, New York, 2000), pp. 84-90.

Laser Physics and Quantum Optics

20. J. Banerji, "Pattern Formation in Non-linear Optics", in *Non-Linear Optics and Laser Spectroscopy*, Eds. S. C. Abbi and S. A. Ahmad, (Narosa, New Delhi), pp 164-190 (2001)

Planetary Atmospheres and Aeronomy

21. Chandra H, Jayaraman A, Ramaswamy S and Acharya Y B, "Temperature Structure and Dynamics Studies by Rayleigh Lidar", in *Advanced Technologies in Meteorology*, Tata McGraw-Hill Pub. Co., Ltd., edited by R K Gupta and S Jeevananda Reddy (1999).

22. Chandra H. and Som Sharma, "Long Term Changes in Ionosphere", in *Long Term Changes and Trends in the Atmosphere*, ed. By Gufran Beig, New Age International (P) Limited, Publishers New Delhi, India, 109-126 (2000).

23. Gupta S.P., "Lightning Middle Atmosphere Interaction", *COSPAR Bulletin No.149*, page 142-143 (2000).

24. Gupta S.P., "Solar Cycle Variation of Stratospheric Conductivity over Low latitude", *Adv. Space Res.*, **26**, 1225-1229 (2000).

25. S.P. Gupta , "Two Stream Instability in E-region over Magnetic Equator during Morning Hours", *Adv. Space Res.*, **26**, 1257-1261 (2000).

26. Lal S., Y. B. Acharya, D. Chand, P. Rajaratnam, and B. H. Subbaraya, "Changes in the Vertical Distribution of Trace Gases over Hyderabad", in *Long Term Changes and Trends in the Atmosphere* Ed. G. Beig, New Age international publisher, *New* Delhi, p.320-334 (2000).

27. Sheel V. and S. Lal, "Long Term Trends in Sulfur Hexafluoride", in *Long Term Changes and Trends in the Atmosphere* Ed. G. Beig, New Age international publisher, New Delhi, p.351-366 (2000).

Earth Sciences and Solar System Studies

28. R. Ramesh, "A 300 year Record from a Silver Fir (*Abies pindrow*) Tree from Pahalgam, Kashmir: Evidence for Little Ice Age in India", in: *IGBP in India-a status report on projects* (ed.s R Narasimha et al), Indian National Science Academy, New Delhi, India, pp.314-318.

29. R. Ramesh, "Paleomonsoonal Records from Marine and Land Based Geological Deposits in the India Region", in *IGBP in India-a status report on projects* (eds. R Narasimha et al.), Indian National Science Academy, New Delhi, India, pp.319-323, (2000).

30. R. Ramesh, "Evaluation of the Paleoclimatic Potential of Climatic Proxies (Corals and Speleothems) from the Indian Region", in: *IGBP in India-a status report on projects* (ed.s R Narasimha et al), Indian National Science Academy, New Delhi, India, pp.324-331, (2000).

Theses Submitted during 2000-01

1. **Ghosh P.**

   Isotopic and Elemental Studies of Gondawan Carbonates and their Implications (2000)

2. **Menon S**

   New Coherence Effects in Systems with Near-Degenerate Levels Driven by Intense Laser Fields(November, 2000)

3. **Vempati Sudhir Kumar**

   Studies in Topics Going Beyond the Standard Electroweak Model (2000)

4. **Patnaik A K**

   Novel Optical Phenomena Induced by External Control Lasers (March, 2001)

5. **Taori A K**

   Investigation in the Low Latitude Daytime Mesos phere Lower Thermosphere Region (2001)

Scientific / Technical Reports Submitted

1. **D.V. Subhedar, Y.B. Acharya, A.D. Bobra, R.R. Shah, K.J. Bhavsar, S.N. Mathur, P.S. Patwal, A.H. Desai, N.V. Dalal, D.B. Pancholi, Narayan Singh and Padam Singh**

   "The Earthing Practice and its Effects on FieldStation Performance", PRL-TN-78-2000.

2. **Rajmal Jain, M. R. Deshpande, H. H. Dave, K.S. B. Manian, N.M. Vadher, A. B. Shah, G. P. Ubale, G. A. Macwan, J. M. Trivedi, C. M. Solanki, V. M. Shah, V. D. Patel, and S. L. Kayasth**

   "GSAT-2 SPACECRAFT – Preliminary Design Review (PDR) Document for Solar X-ray Spectrom eter", July 2000, Published by Geosat Programme Management Office, ISRO Satellite Centre, Bangalore, ISRO-ISAC-GSAT-2-RR-0155.

3. **Rajmal Jain, A. B. Shah, and K. S. B. Manian**

   "Flare Triggering Logic for SLD/SOXS Payload",TPD/ISAC-ISRO, 2000.

4. **Hooper D. and Chandra H.**

   Signal Processing for MST Radar Returns from Mesospheric Altitudes, ISRO Scientific Note, ISRO HQ-SR-47-2000, September 2000.

5. **Shyam Lal, P. K. Patra and S. Venkataramani**

   Measurements of Nitrous Oxide and Methane fromthe Arabian Sea under JGOFS (India) Programme,ISRO-GBP scientific report number ISRO-GBP SR 04 2000

Invited Papers Presented in Symposia/Schools in 2000-01

Astronomy and Astrophysics

1. "Atomic Physics and the Interpretaion of the As trophysical Phenomena", at *Atomic Physics at Frontiers,* University of Roorkee, **Roorkee**, April 13-15, 2000, by **K.S. Baliyan**

2. "Giant Radio Pulses from Pulsars" at the *IAU Colloquium 182, Sources and Scintillations : Refraction and Scattering in Radio Astronomy*, Guiyang, **China**, 17-21 April 2000, by **A. K. Singal**.

3. "An Extremely Rapid Solar Flare Associated Disturbance in the Low Corona", at the *Solar Physics Division (SPD) Annual Meeting*, **Lake Tahoe**, USA, June 19-22, 2000, by **P. Janardhan**, S.M. White and M.R. Kundu.

4. "Scintillation Phenomenon in Nature", at *XXVI Reuniao Anual da SAB*, Mangaratiba - RJ, **Brazil**, 23-27 de julho de 2000, by **Hari Om Vats**, H.S. Sawant, Rupal Oza, K.N. Iyer and Ravi Jadhav.

5. "Multifreqauency Observations of Solar Eclipse of October 24, 1995", at *XXVI Reuniao Anual da SAB*, Mangaratiba - RJ, **Brazil**, 23-27 de julho de 2000, by **Hari Om Vats**, J.R. Cecatto, F.C.R. Fernandes, H.S. Sawant, S. Sharma and K.J. Shah.

6. "Evidence of Clumpy Dust Shell Structure in IRC + 10216 from K band Lunar Occultation Observations", at *International Astronomical Union's XXIV General Assembly: IAU Symposium 205* "Galaxies and Their Constituents at the Highest Angular Resolution" at **Manchester,** UK, August 15-18, 2000, by **T. Chandrasekhar** and Soumen Mondal.

7. "Near IR Studies in PRL" at the *Indo-Japan Seminar on Astronomy and Astrophysics*, Indian Institute of Astrophysics, **Leh**, Sept 27-30, 2000, by **U.C. Joshi**

8. "The Inner Galactic Bulge from Near & Mid IR Surveys", at the *Workshop on Automated Data Analysis in Astronomy*, IUCAA, **Pune,** Oct 9-12, 2000, by S. Ganesh, **U.C. Joshi,** K.S. Baliyan, G. Simon, A. Omont and M. Schultheis

9. "Characteristics of PRL's IR Camera and Image Analysis Procedures", at the *Workshop on Automated Data Analysis in Astronomy*, IUCAA, **Pune,** Oct 9-12, 2000, by **U.C. Joshi**, S. Ganesh, K.S. Baliyan, A.B. Shah and N.M. Vadher

10. "Photometry with NICMOS-3 Array Detector from Mt Abu IR Observatory", at the *Workshop on Automated Data Analysis in Astronomy*, IUCAA, **Pune,** Oct 9-12, 2000, by **K.S. Baliyan**, K. Sanchawala, S. Ganesh, U.C. Joshi and C.R. Shah

11. "Submillimeter Science & Techology - Exciting Opportunities", at the *Symposium on Space Science & Technology: Advances & Applications to Society*, PRL, **Ahmedabad**, October 24-25, 2000, by **Hemant Dave**.

12. "Rapid Optical Variability of Blazar: Mrk 501", at the *XII Canary Islands Winter School of Astrophysics* "Astrophysical Spectropolarimetry", in Tenerife, Canary Islands, **Spain**, Nov. 13-24 (2000), by **A.C. Gupta** and U.C. Joshi.

13. "Multiwavelength Study of the Variability in Blazars", at the *XX ASI-2K Meeting*, Gorakhpur Univ., **Gorakhpur**, Nov. 15-18, 2000, by **K.S. Baliyan**

14. "Study of Variability in BL Lac Objects", at *XX ASI-2K Meeting*, Gorakhpur Univ., **Gorakhpur**, Nov. 15-18, 2000, by **K.S. Baliyan**, S. Ganesh, U.C. Joshi, C.R. Shah, N.M. Vadher and M.R. Deshpande

15. "PRLNIC-3 Observations of Starforming Cloud L1340", at *XX ASI-2K Meeting*, Gorakhpur Univ., **Gorakhpur**, Nov. 15-18, 2000, by **S. Ganesh**, U.C. Joshi, K.S. Baliyan, C.R. Shah, J.K. Jain, G.S. Purohit, K. Sanchawala and A.B. Shah

16. "Near Infrared Photometry of NGC 2453 Cluster", at *XX ASI-2K Meeting*, Gorakhpur Univ., **Gorakhpur**, Nov. 15-18, 2000, by Priya Hasan, G.C. Kilambi and **K.S. Baliyan**.

17. "Spectroscopic Investigations of Planetary Nebulae", Ph.D. Thesis presentation, at *20th Meeting of the Astronomical Society of India and National Symposium on Multiwavelength Astronomy*, Gorakhpur University, **Gorakhpur**, 15-18 Nov. 2000, by **C. Muthu.**

18. "Infrared Spectroscopic Properties of Be Supergiants", at *20th Meeting of the Astronomical Society of India and National Symposium on Multi-wavelength Astronomy*, Gorakhpur University, **Gorakhpur**, 15-18 Nov. 2000, by **Arpit Trivedi** and B.G. Anandarao.

19. "Asteroids" and "Satellites of Outer Planets", two talks at the *Workshop on Meteorites, Asteroids and Planets*, PRL, **Ahmedabad**, India, February 26-March 2, 2001, by **T. Chandrasekhar.**

20. "Living With a Star - The Sun", at the *Workshop on Meteorites, Asteroids and Planets*, PRL, **Ahmedabad**, India, February 26-March 2, 2001, by **P. Janardhan**

Theoretical Physics

Astrophysics

21. " Quark Matter Phase Diagram, Color Superconductivity and Astrophysical Implications", at the *Workshop on Nuclear Astrophysics*, at IUCAA, **Pune**, September 2000, by **Hiranmaya Mishra**.

22. "Astronomy from Space - The New View of Our Universe", at the *U.G.C. Sponsored Research Seminar in Mathematics*, at Sardar Patel University, **Vallabh Vidyanagar**, March 3-5, 2001, by **A.R. Prasanna**.

23. "Electromagnetic Fields on Curved Space Time", at the Conference on *Young Astrophysicists of Today's India - 2001*, at **Kolkata**, March 26-28, 2001, by **A.R. Prasanna**.

24. "Inertial Forces in General Relativity", at the *National Workshop on Black Hole Astrophysics*, at **Kolkata**, March 29-30, 2001, by **A.R. Prasanna**

High Energy Physics

25. "Pseudo-Dirac Neutrinos", at the *DESY Theory Workshop*, DESY, **Hamburg**, Germany, September 26-29, 2000 by **A.S. Joshipura**.

26. "How Much Can We Learn about Top-Quark Gauge Couplings at a Linear Collider?", at the *International Conference on Perspectives in Theoretical Physics*, PRL, **Ahmedabad**, January 8-12, 2001, by **S.D. Rindani**.

27. "Particle Physics with Laser Optics", at the *International Conference on Perspectives in Theoretical Physics*, PRL, **Ahmedabad**, January 8-12, 2001, by **S. Mohanty**.

28. "U(1) Symmetry and R Parity Violation", at the *XIV DAE Symposium on High Energy Physics*, University of Hyderabad, Hyderabad, December 18-22, 2000, by **Rishikesh D. Vaidya**.

Nuclear Physics

29. "Localization in (1+2)-body Random Matrix Ensembles", at the *International Conference on Perspectives in Theoretical Physics*, at Physical Research Laboratory, **Ahmedabad**, January 8-12, 2001, by **V.K.B. Kota**.

Plasma Physics

30. "Terrestrial and Other Planetary VLF Emissions", at the *International Workshop on Seismo Electrmagnetics and Space Science 2000*, at **Agra**, December 19-21, 2000, by **A.C. Das**.

31. "Ionospheric Manifestations of Magnetospheric Processes", at the *AGU Chapman Conference on Storm-Substorm Relationship*, at **Lonavala**, March 12-16, 2001, by **A.C. Das**.

32. "Waves in Dusty Plasmas with High Fugacity", at the *International Topical Conference on Plasma Physics : Colloidal Plasma Science*, at the Abdus Salam International Center for Theoretical Physics (ASICTP), Trieste, **Italy**, July 3-7, 2000, by **N.N. Rao**.

33. "Normal Modes in Dusty Plasmas in the High Fugacity Regime", at the*Third International Meeting of the Working Group on Dust Plasma Interaction in Space*, at International Space Science Institute (ISSI), Bern, **Switzerland**, February 21-26, 2000, by **N.N. Rao**.

34. "Waves in Dusty Plasmas and the Concept of Fugacity", at the *International Workshop Conference on Waves in Dusty, Solar and Space Plasmas*, at Katholieke Universiteit, Leuven, **Belgium**, May 22-26, 2000, by **N.N. Rao**.

35. "Numerical Results on Waves in Dense Dusty Plasmas with High Fugacity", at the *XV National Symposium on Plasma Science and Technology*, at Saha Institute of Nuclear Physics, **Kolkata**, December 5-8, 2000, by **N.N. Rao**.

36. "The Physics of Dusty Plasmas", at the *Seminar on Plasma Physics of Nonlinear Phenomena*, at Institute of Advanced Study in Science and Technology, **Guwahati**, April 3-7, 2000, by **N.N. Rao**.

Nonlinear Dynamics & Computational Physics

37. "Long Range Timecorrelation in Tokamak Edge Turbulence", at the *Workshop on Non-equilibrium Transitions in Plasmas*, at Institute for Plasma Research, **Ahmedabad**, March 8 - 10 2001, by R. Jha, P. Kaw, D. R.Kulkarni and J. C. Parikh .

Laser Physics and Quantum Optics

38. "Control of Decoherence and Relaxation in Quantum Systems" at the International Conference on *Quantum Communication Measurement & Computing*, Capri, **Italy**, July 03-08, 2000, by **G. S. Agarwal**.

39. "Control of Decoherence and Relaxation in Quantum Systems" at the 8th Asia Pacific Physics Conference, Taipei, **Taiwan**, Aug. 07-10, 2000, by **G. S. Agarwal**.

40. "Quantum Optics with Single Atom", Indian National Science Academy Jawaharlal Nehru Birth Centenary Lecture at Punjab University, **Chandigarh**, India, August 25, 2000, by **G. S. Agarwal**.

41. "Freezing and Unfreezing of the Environment Produced Dynamical Evolution", **Plenary Talk** at the International Conference on *Perspectives in Theoretical Physics,* **Ahmedabad**, India, January 08-12, 2001, by **G. S. Agarwal**.

42. "Coherent Control of Atomic Transitions", **Keynote Address** at the National Conference on *Atomic and Molecular Physics*, **Calcutta**, India, January 16-20, 2001, by **G. S. Agarwal**.

43. "Quantum Physics with Single Atoms", **Inaugural Talk** at the Symposium on *Atomic Physics at the Frontiers,* **Roorkee**, India, April 13-15, 2001, by **G. S. Agarwal**.

Planetary Atmospheres and Aeronomy

44. "Recent Results on Aerosol Radiative Forcing from INDOEX" at the *INSA Symposium on Atmospheric Sciences*, 6 May 2000, IISc., **Bangalore** by **A. Jayaraman**

45. "Aerosols and Aerosol Radiative Forcing over the Tropical Indian Ocean" at the *International Workshop on Tropical Environmental Problems in the light of INDOEX*, 7-14 October 2000, IHBT, **Palampur, HP**, by **A. Jayaraman**

46. "Aerosols, Radiation and Cloud Interactions over the Tropical Indian Ocean prior to the onset of the Summer Monsoon" at the *Microsymposium on Climate, Monsoon and India's Water, 66th Annual Meeting of the Indian Academy of Sciences*, 24-26 November 2000, **Goa** by **A. Jayaraman**

47. "A Model Study of the Effect of Pinatubo Volcanic Aerosols on Stratospheric Temperatures", in *Cess Symposium*, Scripps UCSD, **San Diego, USA**, May 2000, V. Ramaswamy, **S. Ramachandran,** G.L. Stenchikov, and A. Robock.

48. "Retrieval of Ozone from Satellite Data Sets", *UN/ESA/COSPAR/ISRO Workshop*, **Dehradun**, November 27, 2000, **Shyam Lal**.

49. "INDOEX Results", *Workshop on Intercontinental Transport and Chemical Transformation*, Frontier Research Institute for Global Change, Tokyo, March 16-17, 2000., **Shyam Lal**.

50. "Marine Aerosols Characteristics", (**two talks**) at the *SERC School Cloud Physics and Atmospheric Electricity*, 15-16 June 2000, IITM, Pune, **A. Jayaraman**.

51. "Solar Radiation, Radiative Transfer, Aerosols and Radiative Effects of Aerosols ", (**9 lectures**) at the *2nd Post-Graduate course in Space Sciences –CSSTE-AP*, 21-31 Aug 2000, PRL, Ahmedabad, **A. Jayaraman**.

52. "Atmospheric Composition and Concepts of Radiative Transfer", (**9 lectures**) at the *CSSTE-AP Course on*

satellite Meteorology and Global Climate, 25 Sept-20 Oct., 2001, SAC, Ahmedabad, **A. Jayaraman**.

53. "Remote Sensing for Pollution Monitoring using Lidar", at the *Laser Spectroscopy for Trace Analysis course*, 11 December 2000, LASTEC, New Delhi, **A. Jayaraman**.

54. "Lidars and Their Applications", at the *3rd Winter School on MST Radar*, 6 March 2000, S.V. University, Tirupati., **A. Jayaraman**.

55. "Upper Atmospheric Electric Field", *3rd Winter School on MST Radar* during 5-9th March, 2001 at S.V. University, Tirupati, **A. Jayaraman**.

56. "Recent Results on Stratospheric Aerosol Modeling", in the *I-STEP Working Group-5 Meeting*, January 18-19, 2001 PRL, Ahmedabad, **S. Ramachandran.**

57. "In-situ Measurements of Plasma Parameters", (**9 lectures**) at the *2nd Post-Graduate Course in Space Sciences –CSSTE-AP*, 18-29 September, 2000, PRL, Ahmedabad, **H. S. S. Sinha**.

58. "Modelling of Radiative Effects of Aerosols" (9 **lectures**) at the *2nd Post-Graduate Course in Space Sciences –CSSTE-AP*, 18-29 September, 2000, PRL, Ahmedabad, **S. Ramachandran.**

Earth Sciences and Solar System Studies

59. "Formation and Early Evolution of the Solar System: Meteoritic Constraints", in *Twentyfifth Symposium on Antarctic Meteorites*, Tokyo, **Japan**, June 21-23, 2000, by **J.N. Goswami**.

60. "Interactions of Energetic Particles and Dust Grains with Asteroidal Surfaces", in *Western Pacific Geophysics Meeting*, Tokyo, **Japan**, June 27-30, 2000 by, **J.N. Goswami.**

61. "Optically Stimulated Dating and its Applications" at the *International Symposium on Dating methods*, Sao Paulo, **Brazil,** June 28 to 30, 2000, by **A.K. Singhvi.**

62. "Chemical and Isotopic Studies of Snow/ice from Central Himalaya", at the *5th Training Course in Glaciology*, GSI, **Lucknow**, Aug. 2000, by **M.M. Sarin.**

63. "Quantitative Reconstruction of Paleomonsoon Parameters from Natural Archives using Stable Oxygen and Carbon Isotopes", at the *66th Annual Meeting of the Indian Academy of Sciences*, **Goa**, Nov. 24-26, 2000, by **R.Ramesh**.

64. "Biochemistry of Himalayan Rivers as an Agent of Long Term Climate Change", at the *66th Annual Meeting, Indian Academy of Sciences*, **Goa**, Nov. 24-26, 2000, by **M.M. Sarin**

65. "Introduction to Stable Isotopes in Hydrology" in *SERC school on Isotope Tracer Techniques for Water Resources Development and Management* held in BARC, **Mumbai**, Nov. 20-24, 2000, by **S.K. Bhattacharya**

66. "Review of Isotopic Studies in Some Indian Rivers: Climate Change and Erosional Perspectives" in *IAEA* Vienna, **Austria,** Dec. 4-6, 2000, by **S.K. Bhattacharya.**

67. "AMS in Oceanography: Applications of Cosmogenic Beryllium-10" at the *9th ISMAS Workshop*, NIO, **Goa**, Dec. 12-16, 2000, **B.L.K. Somayajulu.**

68. "Importance of Riverine C-fluxes for the C-cycle in Asian Countries", at the International Workshop on *"Land-Use changes and the terrestrial carbon cycle in Asia"*, Kobe (**Japan**), Jan. 28-Feb. 2, 2001, by **M.M. Sarin**.

69. "Stable Isotope Variations in Carbonatites: Implications to Mantle Processes", at the *Symposium on carbonatites and associated alkaline rocks*, **Chennai**, Feb.12-13, 2001, by **R.Ramesh**

70. "Remote Sensing of Planets", "Near Earth Asteroids and Planetary Impacts" and "Planetary Science/Exploration - Indian perspective" at the Workshop on *Meteorites, Asteroids and Planets*, PRL, **Ahmedabad**, February 26 to March 2, 2001 by **N. Bhandari.**

71. "Formation of the Sun - the Solar Stellar Connection", "Extinct Nuclides Records in Solar System Objects", and "Laboratory Studies of Planetary Material" at the Workshop on *Meteorites, Asteroids and Planets*, PRL, **Ahmedabad**, February 26 to March 2, 2001 by **J.N. Goswami**.

72. "The Terrestrial Planets", "Meteorites from Planets", "Atmospheres of Terrestrial Planets", and "Cosmic Ray Effects on Solar System Objects" at the Workshop on *Meteorites, Asteroids and Planets*, PRL, **Ahmedabad**, February 26 to March 2, 2001 by **S.V.S. Murty**.

73. "Origin of Earth and Moon" at the Workshop on *Meteorites, Asteroids and Planets*, PRL, **Ahmedabad**, February 26 to March 2, 2001 by **P.N. Shukla**.

74. "Differentiated Meteorites and Planetary Prcesses" at the Workshop on *Meteorites, Asteroids and Planets*, PRL, **Ahmedabad**, February 26 to March 2, 2001 by **G. Srinivasan.**

75. "The Dynamic Earth" at the Workshop on *Meteorites, Asteroids and Planets*, PRL, **Ahmedabad**, February 26 to March 2, 2001 by **Kanchan Pande.**

76. "Dating Terrestrial and Planetary Processes" at the Workshop on *Meteorites, Asteroids and Planets*, PRL, **Ahmedabad**, February 26 to March 2, 2001 by **J.R. Trivedi**.

Lectures Given During 2000 – 2001

At the Second Post Graduate Course in Space & Atmospheric Science

Name	No. of Lectures	Topics
Dr. Shyam Lal	10	Atmospheric Structure, Composition, Hydrostatic Equilibrium, Scale Height Thermodynamics
Dr. A. Jayaraman	10	Solar Radiation, its transfer through atmosphere, Aerosols and Radiative effects of Aerosols
Dr. A. C. Das	10	Magnetospheric Processes and Solar Wind, Solar Activity
Dr. H. S. S. Sinha	10	In-situ Measurements of Plasma Parameters
Dr. S. P. Gupta	10	Ionospheric Irregularities
Dr. U. C. Joshi	10	Basic Astronomy (Planetary, Stellar and Extragalactic)
Dr. B. G. Anandarao	10	Optical, IR and for IR Astronomy
Dr. P. Venkatakrishnan	10	Millimeter Wave, Radio and Solar Astronomy
Dr. Harish Chandra	10	Radio Sounding of the Ionosphere
Mr. R. N. Misra	10	Basic Optics
Dr. N. M. Ashok	10	Photometers and Images
Dr. T. Chandrashekhar	10	Spectral Imaging of the Atmosphere
Dr. Y. B. Acharya	10	Laser Sounding of the Atmosphere
Dr. Varun Sheel	10	Modeling of the Neutral Atmosphere
Dr. S. Ramachandran	10	Modeling of Radiative effects of Aerosol
Dr. R. Sekar	10	Numerical Simulation of Plasma Bubbles

Science at PRL

The work done by the Astronomy & Astrophysics division and the Udaipur Solar Observatory is summarised below:

Hα Emission Line Morphology and Synthetic Aperture Photometry of Starburst Galaxies

Imaging observations of a sample of Markarian galaxies were carried out at Mt. Abu using a 1024x1024 CCD with a 5.2 square-arcmin field of view, through broad band Cousin's R-band and narrow band Hα filters. To study the emission line distribution in a quantitative manner, synthetic aperture photometry was performed on the continuum subtracted Hα images to derive the radial flux distribution. Most of the sample galaxies show a peak in the flux at the centre and a nearly exponentially falling behaviour outwards. In some cases like Mkn 1308, the profile flattens in the outer regions. In case of Mkn 363 and Mkn 1194, the peak emission is off-centered from the nucleus. In general, galaxies with peculiar emission line morphologies show considerable deviations from the exponential profiles, e.g. Mkn 1134 and Mkn 439. Based on the equivalent widths of Hα, we find in some cases that though the flux levels are maximum at the centre, the current SFR is maximum away from the centre. The peak occurs in the inner half kpc in most of these galaxies except in Mkn 363, Mkn 1134, Mkn 1194 and Mkn 1379, all of which show considerable extended extranuclear star formation. The peak is sharp in most cases except in Mkn 363 where it is broad and flattened. This is probably a result of the global star formation seen in Mkn 363.

(A. Chitre and U. C. Joshi)

Study of Spectral Energy Distribution and Variability in Blazars

As a part of an ongoing programme on the monitoring of a number of AGNs, we observed the blazars, viz. Mkn 421, Mkn 501, BL Lac, OJ 287 and 3C 279. Many of these sources exhibited an increased activity during this period. The spectral energy distribution of these objects shows a two humped structure. While the first peak is due to synchrotron radiation from relativistic electrons in the jet, there are several processes proposed for the origin of the second peak, such as Inverse Compton Scattering and External Compton scattering.

(K. S. Baliyan, U. C. Joshi, S. Ganesh, A. C. Gupta and C.R. Shah)

Under an International Multi-wavelength campaign on Blazar variability, B and R band photometric monitoring of 5 blazars, viz. S5 0716+714, OJ 287, S4 0954+658, Mkn 421 and PKS 2155-304, was carried out from Mt. Abu. These blazars have a redshift range ~ 0.03 to 0.40. Flux variation has been observed in these sources. We have detected rapid flux variability in Mkn 501 on a timescale as short as 35 minutes, which is the fastest ever detected in this blazar. Assuming that these variations are produced in the vicinity of a super massive blackhole, the timescale implies a blackhole mass of $3.38 \times 10^7 M_{\odot}$.

(A. C. Gupta and U.C. Joshi).

Detection of Quadrupolar Flows from the Planetary Nebula NGC 4361 from Spatio-kinematic Study

Spatio-kinematic observations were made on the Planetary Nebula NGC 4361 in the [OIII] 5007 Å line using the Imaging Fabry-Perot Spectrometer at Mt. Abu Observatory. The results clearly showed the dramatic reversals of the asymmetry of emission line profiles in two sets of regions that are diametrically opposite to each other. These results support a quadrupolar morphology for NGC 4361, where two pairs of lobes are embedded in an elliptical shell. This 3D morphological model combined with a generalised line profile code matches the observed line profiles well. It was estimated that the time lapse for the ejection of the pairs of lobes was 930 yrs assuming a distance of 1 kpc. The ejection of the two pairs of bipolar lobes might have resulted from the precession of the progenitor star. Our work brings out some important differences between this newly and kinematically established quadrupolar nebula (QPN) and the general class of QPNe (only 6 detected so far). It was found that the fast moving lobes can produce heating at the interfaces with the elliptical shell due to compressional shocks.

(B.G. Anandarao and C. Muthu)

A Study of Star Formation in the Environment near the Massive and Luminous YSO IRAS 05361+3539

Near-infrared photometry and narrow/broad band imaging of the massive and luminous young stellar object (YSO) IRAS 05361 + 3539 were made at Mt. Abu Observatory using NICMOS array. Supplementary JHK data were extracted from 2 MASS archives. From the color-color and color-magnitude diagrams, we identified several faint class II type and about six class I type YSOs in the molecular cloud complex surrounding the luminous YSO. The IRAS 05361+3539 itself was found to be a class I object. Our Br γ and H_2 images show jet/outflow from this object (**Fig. 1.1**), which matches with the axis of the CO outflow detected earlier. The near-infrared and IRAS far infrared spectral energy distribution suggests a possible accretion disk with dust temperatures between 80 – 800 K and extent of several tens to hundreds of AU. These are the first comprehensive JHK photometric observations from

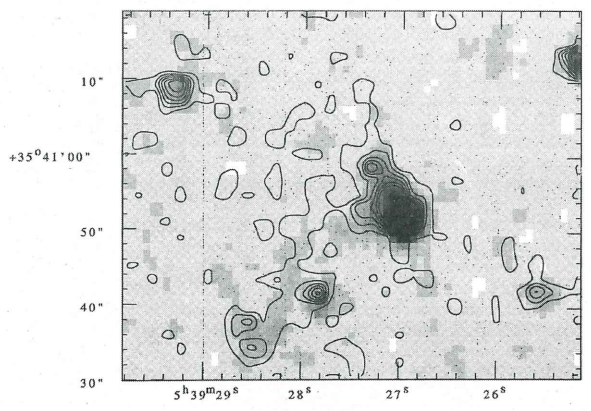


Fig.1.1 Contours of the molecular hydrogen (line + continuum) image overlaid on the K' image, the contours are from 4σ to 9σ levels. The x and y axes are RA and DEC (J2000) respectively.

NICMOS and are found to match very well with the 2MASS data. This work was done in collaboration with A. Chakraborty, D.K. Ojha and T.N. Rengarajan of TIFR, Mumbai.

(B.G. Anandarao)

Near-Infrared Spectroscopy of AGB and Post-AGB Stars

In order to establish infrared spectral characteristic features with the evolutionary sequence among AGB and post-AGB stars we have initiated an observational programme on a selected list of such stars. Using the NICMOS spectrograph on the 1.2 m telescope of the Mt. Abu Observatory, we have so far made JHK spectroscopic observations on 18 selected stars a majority of which show Br γ emission lines, probably signifying onset of energetic photon flux from the central hot core.

(B.G. Anandarao and Arpit Trivedi)

Near Infrared Spectroscopic Study of Eruptive Variable V445 Puppis

An outburst of activity was discovered in the star V445 Puppis. The optical spectrum shows a pronounced hydrogen deficiency which is unusual for a nova. Near infrared spectroscopic monitoring of this star was done

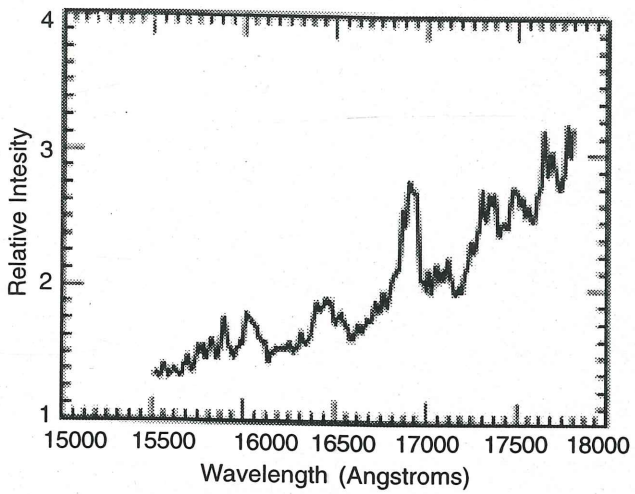


Fig. 1.2 The H band spectrum of V445 Puppis recorded on 2.1.2001 from Mt. Abu Infrared observatory

from Mt. Abu (**Fig. 1.2**). The absence of the hydrogen emission lines of the Brackett and Paschen series is clearly confirmed in our spectra taken in the J, H and K bands. The IR spectra are instead dominated by emission features of C IV, C III and C I. Interestingly a discernible rise in the continuum is seen towards the longer wavelengths from 1.6μm indicating the presence of a

cooler component. The unusual spectra of V445 Puppis indicate that it may be a prototype of a new class of symbiotic binaries in which a companion red giant, whose envelope has been stripped to its hydrogen deficient layers, is transfering matter to the compact white dwarf. Such "Helium novae" have been proposed theoretically in the recent past but not been observed so far.

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

Lunar Occultation Observations of the Mira Variable U Ori and its Mode of Pulsation

Successful K and H band lunar occultation observations of the oxygen-rich Mira variable U Ori (spectral type M6-M9.5e; period 370 days) were carried out with the recently built two channel IR high speed photometer. The photometric phase of U Ori at the time of the occultation was 0.33. A uniform disk model fitted to the K band occultation light curve yielded a value of 11.3 ± 0.5 mas for the angular diameter of U Ori. Distance to U Ori is estimated to be 283 ± 53 parsec from period-luminosity relation and our own photometry measurement at K band. Inspite of the distance uncertainty for U Ori it appears to be pulsating in the first overtone mode and not in the fundamental. Near Infrared spectra using NICMOS 3 are being taken at different photometric phases to study its spectral type variation with phase.

(S. Mondal and T. Chandrasekhar)

Spectral Classification of M Giants using Infrared Spectroscopy

The most studied signatures in the infrared spectra of cool stars are the ($\Delta v=2$) bands longward of 2.29μm due to CO absorption. The strengthening of CO absorption with decreasing temperature and increasing luminosity has been suggested for two-dimensional spectral classification. The K band spectra also show strong features of the NaI doublet at 2.208μm and CaI triplet at 2.263μm. With the above aims in mind, IR spectroscopy with the NICMOS spectrometer was carried out on about a dozen late type giants with known spectral types ranging from M2 to M8. The equivalent widths of the first overtone band heads from $^{12}CO(2,0)$ at 2.29μm

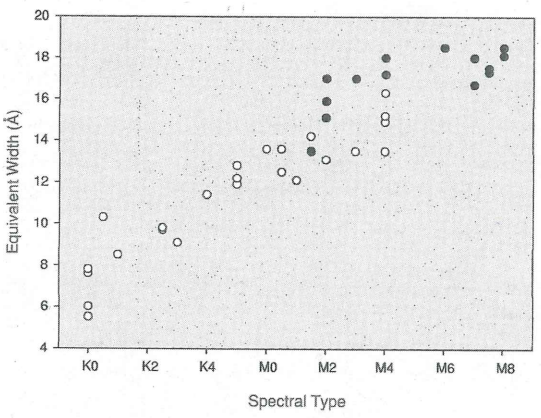


Fig. 1.3 Relationship between the equivalent width of the $^{12}CO(2,0)$ over tone band head in the spectra of K and M giants and their spectral type. Closed circles represent our data covering the M giant region. For comparison data from other workers covering the K giant region is also shown.

were measured from the spectra. **Fig. 1.3** shows the almost linear relationship between equivalent widths of the $^{12}CO(2,0)$ band head and the spectral type. This work establishes the suitability of using $^{12}CO(2,0)$ overtone bands for spectral type determination.

(Anandmayee Tej and T. Chandrasekhar)

New Results on the Inner Central Region of the Milky Way Galaxy

Using DENIS Survey observations in the near IR, a complete and homogeneous map of the extinction over a large area (> 20sq. degrees) around the Galactic Centre was constructed for the first time. The extinction in the inner region of the Galaxy is found to be patchy, being very high in some regions. It was noticed that in the high extinction regions, J and to some extent H band data were undersampled, leading to a lower estimation of extinction in the work reported earlier. Keeping these points in mind, we have made deep J and H band observations of selected regions in the inner Galaxy, using 1.2m telescope at Mt. Abu and NICMOS camera.

Extinction towards the Inner Galaxy was studied with data from the 2MASS Survey and the ISOGAL da-

tabase. While the results from the 2MASS survey extends the work previously reported with DENIS, newer insights with regard to the stellar population distribution in the IGB (Inner Galactic Bulge) region have been obtained. At mid infrared, observations of the ISOGAL survey by ISO were used to make a mosaic of the view of the Inner Galactic Bulge at 7 microns (**Fig., see cover page**) (for which extinction is negligible). Quite a few dark regions with a great deal of extinction even at mid-IR wavelengths are detected. These have been used to study the mid-IR extinction properties along those lines of sight. Observations complementary to ISOGAL, from the 'GPSURVEY' ISOCAM Survey of the Galactic Plane were investigated and a comparative study was published. With the DENIS and ISOGAL data, it was also possible to study further the near infrared variability properties of the stars in the IGB and the possible variable candidates were identified. A study of MACHO variables in the ISOGAL database for the Baade's Window was also completed. Spectroscopic results for some of the ISOGAL sources have been discussed based on optical spectroscopy from Kavalur, India. A study of the Galactic Bulge was performed using data from the ISOGAL, DENIS and 2MASS surveys. This work is done under the Indo-French project, supported by IFCPAR.

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

Study of H_α line profiles in Be stars

The H_α line profiles of a large sample of Be stars have been obtained using the Fibre Linked Astronomical Grating Spectrograph from Mt. Abu Observatory. A good correlation is found between the full widths of the profiles and the stellar rotational velocity (vsini). This indicates that kinematics is the dominant factor in line broadening in Be stars vis-à-vis other mechanisms like thermal broadening, shear broadening and non-coherent scattering broadening. A significant number of stars display a wine bottle emission profile that has a significantly large peak-to-continuum intensity ratio compared to other Be stars. From this it can be inferred that such stars have low vsini values, i.e. a low inclination of their rotation axes.

(D.P.K. Banerjee, S.D. Rawat and P. Janardhan)

Observations on Pulsars and Quasars using GMRT

An observational programme using the GMRT facility has been initiated to study pulsars. A sample of selected pulsars are planned to be studied simultaneously from GMRT and Ooty Radio Telescope at different frequencies. This will help in studying in detail the triggering mechanism for the intriguing enhanced emission from pulsars observed earlier from Rajkot IPS station. So far two pulsars (0950+08 and 1133+16) were observed with the GMRT.

A few selected quasars were observed with the GMRT to obtain brightness distribution maps. These quasars appear to have very large radio sizes. These sources have somehow been able to overcome the ram pressure of the intergalactic medium to a higher degree than similar sources and have thus attained larger size. The brightness distributions of these galaxies could throw light on the cause for their large radio sizes.

(A.K.Singal)

Observations of Variation in Solar Coronal Rotation with Altitude

The first measurements in radio emission of differential rotation in solar corona were made. Rotation as a function of height was inferred from the disk-integrated simultaneous daily measurements of solar flux at eleven radio frequencies in the range of 275-2800 MHz. Based on the model calculations, these radio emissions originate from the solar corona in the estimated average height range of ~ (6-15)x10^4 km above the photosphere. The investigations indicated that the sidereal rotation period at the highest frequency (2800 MHz), which originates from the lower corona around 6x10^4 km is ~ 24.1 days. The sidereal rotation period decreased with height to ~ 23.7 days at the lower frequency (405 MHz), which originates at 13x10^4 km. Since these investigations are based on disk-integrated solar flux at radio frequencies, it is difficult to say whether these systematic variations in sidereal rotation period are partly due to the latitudinal differential rotation of the solar corona. This work was done in collaboration

with Mehul Mehta (J.J. College, Nadiad) and the Interplanetary Medium Group (INPE), Brazil.

(Hari Om Vats)

Self-organized Criticality in the Solar Active Regions

We have applied the concept of self-organized criticality to solar active regions. As self-similar temporal variability and power-laws are the fundamental conditions for the characterization of criticality in solar active regions, we computed wavelet transforms and frequency distribution of two solar observations: (a) a metric noise storm at 164 MHz and (b) a radio pulsation at 1.6 GHz. The observations were made by Nancay Radioheliograph and by Brazilian Solar Spectrograph. The frequency distributions provide slope exponents $\alpha_{164\ MHz}$= -1.65 and $\alpha_{1.6\ GHz}$= -2.1. The global wavelet spectral slopes are positive: $\beta_{164\ MHz}$ = + 0.56 and $\beta_{1.6\ GHz}$ = + 0.57. This indicates that the solar magnetic field in msec scale could be in critical state, which leads to avalanches of many small intermittent particle acceleration events. This work is done in collaboration with the INPE, Brazil.

(Hari Om Vats)

Study of Interplanetary and Terrestrial Effects of an Earth Directed Coronal Mass Ejection

An earth-directed coronal mass ejection (CME) occurred near the centre of the solar disk at 04:35 UT on May 12, 1997. We observed its effects using IPS array at Rajkot and digital ionosonde at Ahmedabad. The disturbance was found to have plasma density ~ four times more than that of the ambient plasma at a distance of ~ 0.5 AU from the Sun. The most peculiar aspect of this CME was that the disturbance moved slightly slower than the ambient medium. As SOHO and IPS estimates of solar wind were quite different, it appears that the difference could be due to the projection effect of SOHO image. Though the disturbance was not severe, its impact on Earth's environment produced a geomagnetic storm. The ionospheric effects of soft X-rays from this solar flare were observed by a digital ionosonde at Ahmedabad in the form of excess ionization (~ 1200 e/cm^3) in the D-region of the ionosphere. This work is done in collaboration with INPE, Brazil and Department of Physics, Saurashtra University, Rajkot.

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

Anisotropic Structure of the Solar Wind in its Region of Acceleration

New experimental data on the electron density irregularities have been obtained from simultaneous recordings of spacecraft signals at several widely-spaced ground stations. A cross-correlation analysis using phase and/or frequency fluctuations yields the outward flow speed of the irregularities. In contrast to earlier amplitude fluctuation measurements, correlation time lags across an intercontinental baseline may reach several tens of seconds. Temporal spectra of the amplitude fluctuations, on the other hand are sensitive to both velocity of the irregularities and the anisotropy coefficient. This technique was applied to experimental data recorded during the solar occultations of the Venera spacecraft. Typical values of the anisotropy coefficient are determined to be less than 2 at solar distances outside 15 $R_\odot$ and greater than 2 inside this distance. It is suggested that the radial dependence of the anisotropy is governed primarily by the coronal magnetic field strength. This work was carried out in collaboration with M.K. Bird, Radioastronomisches Institut, Bonn and A. Efimov of the Institute of Radio Engg. & Electronics, Russian Academy of Sciences.

(P. Janardhan)

Observations of Interplanetary Scintillation during the 1998 Whole Sun Month: A Comparison Between EISCAT, ORT and Nagoya Data

Observations of interplanetary scintillation (IPS) allow accurate solar wind velocity measurements to be made at all heliographic latitudes and at a range of distances from the Sun. The data may be obtained with either single, double or multiple antennas, each requiring a different method of analysis. IPS data taken during the 1998 whole sun month (30th July - 31st August 1998) by EISCAT, the ORT (Ooty Radio Telescope), In-

dia, and the Nagoya IPS system, Japan, allow the results of individual methods of analysis to be compared. Good agreement is found between the velocity measurements using each method, and when combined an improved understanding of the structure of the solar wind can be obtained. This work was carried out in collaboration with P.J. Moran, University of Wales, UK; M. Tokumaru, Solar-Terrestrial Environment Laboratory, Japan and V. Balasubramanian, TIFR.

(P. Janardhan)

Radio Detection of a Rapid Disturbance Launched by a Solar Flare

The direct observation of motion associated with a solar flare at an unprecedented speed of 26,000 km s^{-1} was detected. The motion is seen from a radio source at 0.33 GHz. At its peak, the source covers a quiet region of dimension 500" and had excited coronal features that continued to radiate after it passed. The observed motion of the source at a fixed frequency, low polarization, and moderate bandwidth are more consistent with the typical properties of moving type IV radio bursts than with classical coronal shock-associated type II bursts. But any disturbance at such a high velocity must be highly supersonic and should drive a shock. We speculate that the disturbance is associated with the realignment of magnetic fields connecting different portions of an active region. This work was carried out in collaboration with Steven White and M.R. Kundu, University of Maryland, USA.

(P.Janardhan)

Optical and X-ray Observations of Impulsive and Gradual Solar Flares

A detailed analysis of an impulsive and gradual flare, which occurred on 10 March 2001 and 25 November 2000 respectively, is in progress. The soft X-ray telescope (SXT) and hard X-ray telescope (HXT) aboard YOHKOH mission made observations of these flares, and they are being analysed in view of Hα observations taken at State Observatory, Nainital. The overlay of HXT and SXT images indicate that hard X-ray emission (>10 keV) in impulsive events, in addition to gradual flares, is possible near the top of the loops, which shows that very high temperatures (>10^7 K) may occur near the loop tops during reconnection. This work is done in collaboration with W. Uddin, T. Sakao, R. Chandra and T. Kosugi.

(Rajmal Jain and K. J. Shah)

Photoionization Cross Sections from the Fine Structure Levels of Ni XIX

Photoionization cross sections, excitation rates and f-values for a large number of atoms and ions in their various stages of ionization are required for modelling the astrophysical and fusion plasma. However, it is not easy to get such data on complex systems in the laboratory and one resorts to involved calculations. A sophisticated calculation was carried out for the photoionization cross sections from fine structure levels of Ni XIX incorporating relativistic effects. The lowest three levels were used in the initial and final state wavefunctions. The results show substantial improvement over the LS calculations. This work was done in collaboration with University of Delhi.

(K. S. Baliyan)

A Small Robotic Telescope for Imaging Observations of Transient Events

An experimental robotic telescope (20cm aperture) equipped with a CCD is being set up at Mt. Abu. The system, which is being designed to respond to an e-mail trigger, should be capable of detecting GRBs up to m_v = +16 for an integration time of ~30 sec in relatively dark skies.

(N.M. Ashok, T. Chandrasekhar, D.V. Subhedar).

Solar X-ray Spectrometer (SOXS)

The Lab model of all three packages of SOXS' Low Energy Detector (SLED/SOXS), viz. the detector, front-end and processing electronics have been successfully designed, developed and fabricated, and later an integral line test of the whole payload was conducted at Technical Physics Division, ISAC, Bangalore. Sensitiv-

ity of the detectors in terms of their effective area as a function of X-ray energy has been calculated.

(Rajmal Jain, H. H. Dave, M. R. Deshpande, K. S. B. Manian, N. M. Vadher, A. B. Shah, G. P. Ubale, G. A. Panchal, C. M. Solanki, V. M. Shah, V. D. Patel, and S. L. Kayasth)

Submillimeter Science and Technology Programme

Due to atmospheric absorption, the observations of the Universe in the submillimeter region (300GHz-4THz) can only be explored from high above the atmosphere and from space. A laboratory facility is under construction at PRL to support tunable high-resolution spectroscopy in the submillimeter wave region. This facility will help future science study missions on Planetary Atmospheres and Astronomy.

(H. Dave, U. C. Joshi, Shyam Lal, J. Pabari, R . Singh, V. Choudhary and V.D. Patel)

Frequency Counting using Micro-Controllers for Astronomical Applications

An efficient and cost-effective frequency counter has been made using an Atmel 89C2051 micro-controller (μC). The design can use any μC of the 8051 family. The circuit counts frequency and sends to a PC via the serial port. After sending the data the program again returns to the main routine, in which it clears the timer and counter and resets them and then starts counting again. This system has been put to use in the photon-counting operation of the PMT detector employed in our Fabry-Perot Spectrometers.

(F.M. Pathan, R.T. Patel and B.G. Anandarao).

Variation in the Seismic Radius of the Sun

The *f*-mode is believed to be a surface gravity mode and its frequency is essentially independent of the stratification in the solar interior. Hence, these frequencies provide an accurate measure of the solar radius. We have used centroid frequencies of solar *f*-modes obtained from SOHO/MDI to study the temporal evolution of solar seismic radius **(Fig. 1.4)**. The data consist of twenty non-overlapping data sets covering a period of four years from 1996 to 2000 in the rising phase of the current solar cycle. The seismic radius which decreases with the increase in activity level reveal a 1 year periodicity which may be associated with the solar cycle variation. However, the origin of this oscillatory behaviour is not clear.

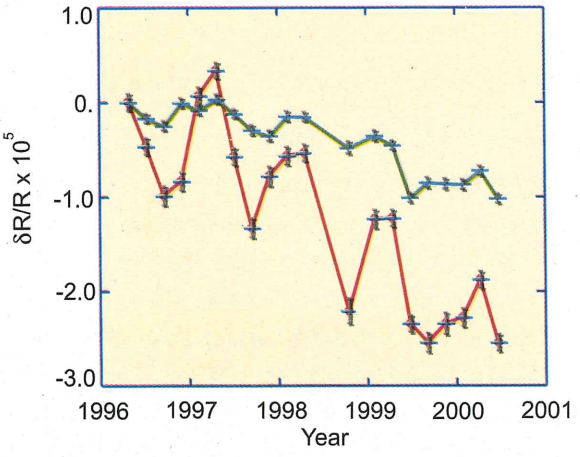


Fig. 1.4 Relative difference in the radius of the sun as inferred from f-mode frequencies obtained from SOHO/MDI. The red line is the result as derived from frequency tables containing splitting coefficients up to 36th order and covers the degree range of 217 to 286. The green line shows the result using the frequency tables containing splitting coefficients up to 6th order and includes modes of degree range between 100 and 200.

(Kiran Jain, S.C. Tripathy and A. Bhatnagar)

Solar Rotation Rate in the Upper Convection Zone from Inversion

It is known that the solar differential rotation and other symmetry breaking factors like magnetic field can lift the degeneracy of the solar acoustic modes and split the eigen frequencies. We find that the first few odd order splitting coefficients from both GONG and SOHO instruments vary systematically with the solar cycle. By inverting these coefficients using 1.5D regularised least square method, we have inferred the solar rotation rate in the upper convection zone. The residual rotation rate

in the outer layers appears to be correlated with the solar activity cycle.

(Kiran Jain, S.C. Tripathy and A. Bhatnagar)

Cross-correlation between Various Solar Activity Indicators

The solar activity is defined by various indicators such as sunspot number, 10.7 cm radio flux, flare index, coronal index, magnetic index etc. The emergence of these indices indicate the time dependence associated with different physical processes which are localised at different layers of the solar atmosphere. In our analysis, we show that the hysteresis is present among many pair of activity indices during last couple of solar cycles which can be expressed as a hierarchy of delay times behind the leading index. We also find that the upper chromospheric indices which are produced by plages, evolve more slowly than the sunspot number of the same active region and 10.7 cm radio flux behaves more like sunspot numbers.

(Kiran Jain)

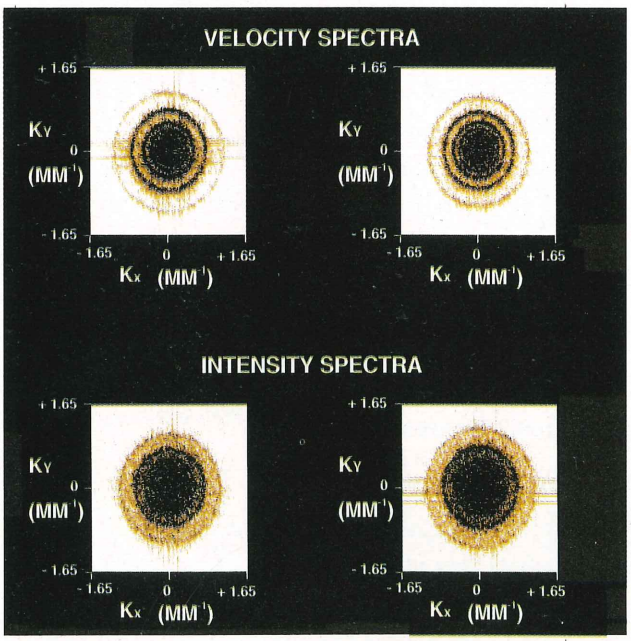


Fig. 1.5 Ring diagrams for velocity (top) and intensity (bottom) from GONG+ prototype data. The rings on the left were computed at 3.5 mHz from the three-day long time series and those on the right are at 4mHz.

Comparison of GONG + Velocity and Intensity Local Acoustic Spectra

The local acoustic spectra of small regions over the solar surface have been studied by using the technique of ring-diagrams (**Fig. 1.5**). The numerical magnitude of the measured power in V and I differ by a factor of 10. A suitable normalization is applied to both the spectra in order to investigate any observable difference in the size and power of the rings. The frequency dependence of the shift is negligible below the acoustic cutoff frequency around 5.3 mHz and substantial above the cutoff. Also, these shifts increase with degree which suggests that the effect becomes more pronounced as the wavelength of the waves approaches the dominant spatial scale of granulation. This is consistent with current theories of mode excitation wherein the convective background is partially correlated with the oscillations. The frequency shift may thus be the signature of the strong correlation between V and I in granulation. This work was done in collaboration with Frank Hill and Cliff Toner of National Solar Observatory, USA.

(Kiran Jain)

Search for Helioseismic Response of Impulsive Solar Flares

We have analysed time series of magnetic, velocity and intensity full disk images obtained at 1024x1024 pixel-resolution, around an X2.3/3B flare observed on June 6, 2000/14:58-15:25 UT, by the upgraded GONG+ instrument, recently made operational at NSO, Tucson. We obtained the ring diagrams corresponding to 60x60 pixel areas around the flare in a complex active region; a simple sunspot; and a quiet site for inter-comparison of power. As the ring diagrams are known to be affected by geometric effects, we obtained corresponding ring diagrams at the same geometric locations on a reference day, i.e., June 11, 2000. We find that there is no appreciable, unambiguous difference between the flare and quiet regions at various frequencies. This work was carried out in collaboration with Cliff Toner, and Frank Hill, NSO, Tucson.

(Ashok Ambastha)

Search for Spatial Variability in the Solar Acoustic Spectrum

Motivated by the various examples of spatial variability in the power of the acoustic spectrum, we attempted to look for spatial variability in the peak frequency of the spectrum, which would be relatively less affected by the viewing angle. However, the determination of this peak frequency on a spatial scale of a single pixel (8 arc seconds for the GONG data) is limited by the stochastic variations in the power spectrum presumably caused by the stochastic nature of the excitation process. Averaging over a large number of spectra (100 spectra from a 10 x 10 pixels area) produced a more stable spectrum. The peak frequencies of 130 locations were found to be distributed with a FWHM of about 130 mHz. A map of the spatial variation of this peak frequency did not show strong feature with statistically significant deviation from the mean of the distribution. Likewise, the scatter in the peak frequencies masked the detection of magnetic field induced changes in the peak frequency. On a much larger scale, the N latitudes showed a slightly lower value of the peak frequency as compared to the S latitudes, although the difference (25 mHz) is barely larger than the *rms* spread (20 mHz).

(P. Venkatakrishnan, B. Kumar and S.C. Tripathy)

Speckle Reconstruction of Solar Features

A sequence of short exposure H-alpha images obtained at USO, were processed using speckle reconstruction techniques. The sequence overlapped a small subflare which showed interesting evolution, commencing at two small kernels and spreading as a faint ribbon to a neighbouring brightening. Because of the high resolution employed, the evolution of the fine structure in the ribbon could be clearly seen. In another sequence of continuum images (16 nm centered at H-alpha), obtained at Kodaikanal Tunnel Telescope, the evolution of tiny brightenings within a small pore could be monitored. This could be the small end manifestation of umbral flashes, generally seen in fully developed sunspots. The intra-pore brightenings could be seen only as a result of employing high resolution techniques like speckle reconstruction. This work was done in collaboration with R. Sridharan of IIA, Bangalore.

(P. Venkatakrishnan)

Spectropolarimetry of Solar Active Regions

The Kodaikanal Tower/Tunnel Telescope was used to obtain polarized line profiles of the Fe lines at 630.2 nm and 630.1 nm. The polarization created by the 3 mirror coelostat was successfully eliminated. The resulting corrected profiles were inverted to obtain the parameters like total magnetic field strength, line depth, doppler velocity, doppler width and fill factor. In a few places on the magnetic polarity inversion line, the profiles departed substantially from the standard canonical forms to prevent straigtforward implementation of the inversion routines. In this case, a special method was adopted that could detect flows along the field, which crossed over the polarity inversion line. These flows always seemed to be from weak field to strong field regions. This work was done in collaboration with K. Sankarasubramanian of IIA, Bangalore.

(P. Venkatakrishnan)

Chromospheric Magnetic and Velocity Field of Active Region NOAA 6555

The Active Region NOAA 6555 was one of the most flare productive one during the solar cycle-22. We have used high spatial resolution magnetic and velocity field obtained from Huairou Solar Station during its disk passage to study the nature of flare and surge sites. The AR displayed mostly surge activity during the initial phase (March 21-22) and flare activity later (March 24-30). The two types of activities occurred at distinctly different locations. The site of surge activity had continuous emergence of parasitic flux, whereas the initial flare location had narrow channels of opposite polarity. The flares were triggered by emerging flux. The sites of large flares were also marked by crossing of magnetic and velocity field neutral lines. The vertical gradient of magnetic field up to chromospheric heights was found to vary on daily basis and rapidly before the onset of large flares.

(Debi Prasad Choudhary and P. Venkatakrishnan)

Chromospheric Magnetic Field of Solar Active Regions

The three-dimensional magnetic field structure of 137 solar active regions is studied by comparing the observed and computed chromospheric magnetograms. The model chromospheric field is obtained by extrapolating the observed photospheric field into chromosphere with the potential (current-free) magnetic field model in Cartesian geometry. The best correlations of the observed and model chromospheric magnetogram are found at the height of 800 km, which also corresponds to the height of the line formation for CaII 854.2 nm. In the weak field range, within 300 G, most of the observed field is close to the potential field. However, a departure of about 50 G is observed in few active regions. For field values greater than 500 G, the observed field do not always match the model. Whereas, a part of this could be due to the magnetogram calibration, it might also originate from the "non-potentiality" of the chromospheric field. In the case of the long-lived active regions, which make multiple disk passages, the strong-field "non-potentiality" is observed during their initial phase, and converge to potential field configuration later. This work was carried out in collaboration with T. Sakurai of National Solar Observatory of Japan, Mitaka, Tokyo.

(Debi Prasad Choudhary and P. Venkatakrishnan)

Observational Study of Three Dimensional Magnetic Field Structure and Mass Motion in Active Regions

The spectro-polarimetric observations of active regions were carried out, in the spectral lines of Si I 10827.1 Å and He I 10830 Å, to study the three dimensional magnetic field structure and associated plasma flow properties. The comparison of SiI and HeI magnetograms with the potential field model, show that a large fraction of the magnetic field is consistent with the potential field structure, by assuming that the height difference between the origin of two lines is about 1200 km. The slope of the scatter plot between Si I and He I magnetograms is 0.5, 0.76 in emerging flux and a larger active region respectively. These values are smaller compared to the scatter plot slopes obtained with Kitt Peak chromospheric magnetograms, which are 0.83 and 0.9 respectively. Considering the height difference between these two sets of chromospheric magnetograms, this implies that the magnetic field spreads out faster near the transition region heights. The Dopplergrams obtained by determining the centroid of the asymmetric line profiles show that the chromospheric red-shifted regions are located in the magnetic neutral line areas. This work was carried out in collaboration with Yoshinori Suematsu and Kiyoshi Ichimoto of National Solar Observatory of Japan, Mitaka, Tokyo.

(Debi Prasad Choudhary)

Eruptive Prominence Events and Their Association with Coronal Mass Ejections

We have studied time evolution of prominences using USO's full disk H-alpha and GONG full disk magnetograms observations obtained during 1999 and 2000, to infer about eruption of quiescent prominences. Statistical parameters of eruptive events, such as, the distribution, most probable life-time, global sense of magnetic field, etc., have been deduced for more than 70 eruptive events out of a total of 220 observed filaments/prominences. For our study, we have excluded those prominences for which the life-time estimation is rather uncertain, viz., relatively long lived prominences, that rotated away beyond the W-limb without erupting.

(Ashok Ambastha, Reetu Agrawal, and Kumud Pathak)

Solar and Interplanetary Signatures of Major Geomagnetic Storms during 1997-2000

The study of the solar origin of mass ejections and their interplanetary signatures that lead to intense geomagnetic storms is important for understanding Space Weather. During the ascending phase of the recent solar cycle, the solar and interplanetary signatures of coronal mass ejections (CMEs) observed by Large Angle Spectrometric Coronagraphs aboard SOHO, have been examined. These CMEs were responsible for causing intense geomagnetic storms (Dst < -100 nT) on the earth.

We have studied the relationship of these CMEs with halos, long-duration events, flares and eruptive prominences. In addition, investigation of the role of the initial expansion speeds of halos in determining the time of their arrival at the earth for prediction purpose, has also been made.

(Nandita Srivastava)

Solar Driver of the Major Geomagnetic Storm Associated with the CME of March 29, 2001

The coronal mass ejection of March 29, 2001 was responsible for the most intense geomagnetic storm of the current solar cycle till date. The CME was associated with one of the major flare (X1.7) of the current solar cycle in the active region NOAA 9393. The flare was recorded in H-alpha at Udaipur Solar Observatory and the associated CME was recorded by coronagraphs aboard SOHO. A comparison of the CME of March 29, 2001, with a set of geo-effective halo CMEs associated with X-class flares showed that the strength of the geomagnetic storm at the earth is well correlated with the speed of the halo. Our study further shows that the fast ejection is responsible for building up the ram pressure at the earth's magnetosphere. This may serve as a useful tool in the forecasting of intense geomagnetic storms.

(Nandita Srivastava and P. Venkatakrishnan)

Astrophysics

Effect of Rotation on General Relativistic Enhancement of Neutrino Heating Rates

GTR effects have been shown to increase the neutrino heating rates in supernova. As rotation is an important aspect of all cosmic sources, using the external field of Hartle-Thorne solution for a slowly rotating object, we investigate the effects of including rotation in the treatment of heating rates. We find that the heating rates are substantially increased from the case of non-rotating stars. This work is done in collaboration with Dr. Srubabati Goswami of Saha Institute of Nuclear Physics, Calcutta.

(A.R. Prasanna)

Advection Dominated Flows around a Rotating Compact Object

Advection dominated flows around black holes using self-similar class of solutions have been very popular in the last decade and models based on this prescription have turned out to be quite successful. Recently analysis has been made of such solutions, through the introduction of pseudo-Newtonian potential perturbatively wherein it was demonstrated that the perturbative analysis can give better representation into the parameter space of the solutions. It was found that for certain values of viscosity parameter α and the gas parameter γ the perturbation could develop a singularity and consequently the assumption of self-similarity may be violated. However, as is known, cosmic sources have intrinsic rotation, it is indeed necessary to bring into the discussion of kinematics of *Coriolis force*, which generally induces rotation of the surrounding space time. Using a generalized set of fluid equations that include the *coriolis force* along with the centrifugal and pressure gradient forces, we have reanalysed the class of self-similar solutions, again using the pseudo-Newtonian potential. We obtain a slightly modified behaviour of the physical parameters, but the most important new aspect discovered is that the inclusion of the Coriolis term renders the parameter space available for most values of α, γ, $0 < \alpha < 1$ and $1 < \gamma < 1.66$ for co-rotating flow and almost the entire parameter space for counter-rotating flow. Further, it has also been seen that the flow patterns with self-similar solution admits both positive and negative values for the Bernouli parameter indicating that the class of solutions could admit energy flux inwards and outwards.

(A.R. Prasanna and B. Mukhopadhyay)

Atomic and Molecular Physics

First Born Amplitudes for Near Circular Rydberg States

In our continuing investigations of Rydberg atoms, we have already reported some interesting results. Here, we have obtained *compact* formulas of the first Born amplitude for some selected transitions involving *near* circular states. The derivation became possible by using cylindrical coordinates for mathematical manipulations, a technique departing from the conventional method which uses spherical polar coordinates.

(D.P. Dewangan)

The Tricomi Expansion in Rydberg Collisions

As is well known, the calculation of quantum mechanical cross section for transitions between high Rydberg atomic states suffers from inaccuracies resulting from the cancellation errors caused by rapid oscillations of the initial and final state wave functions. To surmount the problem of cancellation errors, an asymptotic expansion method based on the Tricomi expansion has been used in the literature. However, the region of validity of this method has not yet been satisfactorily investigated. We have already derived some compact expressions of the first Born cross sections. We have found that the use of the recurrence relations of the Jacobi polynomials enables us to perform accurate numerical computation of the first Born cross section for fairly large values of both the initial and final principal quantum numbers. For large quantum numbers, using the known asymptotic behaviour of the Jacobi polynomials, the first Born amplitude is expressed in terms of the Bessel functions. This method enables us to compute the first Born cross sections accurately and also to

study the region of applicability of the Tricomi expansion method.

(D.P. Dewangan)

High Energy Physics

No-Go for Degenerate Neutrinos

The possibility of radiatively generating parameters for solar and atmospheric neutrinos starting with degenerate masses of neutrinos was investigated. It was shown in a model independent way that standard scenario with only one Higgs doublet cannot generate the required parameters. This work was carried out with Dr. Amol Dighe of CERN, Geneva, Switzerland.

(A.S. Joshipura)

Neutrino Anomalies and Extra Large Dimensions

Quantum field theories in more than four dimensions can explain small neutrino masses when some of the extra dimensions are chosen to be relatively large - around *mm* scale. Such theories by themselves cannot reproduce different mass scales and mixing angles needed for understanding the observed neutrino oscillation phenomena. We investigated possibilities of explaining all neutrino anomalies in this context. It was shown that starting with degenerate neutrinos, one can generate mixing angles and mass scales needed to understand solar and atmospheric neutrino anomalies when this model is embedded in a higher dimensional theory. Simultaneous explanation of the LSND results requires some pre-existing neutrino mass structures. A specific example based on Zee model is shown to explain all neutrino anomalies. This work was carried out with Dr. Amol Dighe of CERN, Geneva, Switzerland.

(A.S. Joshipura)

Leptogenesis and Left Right Symmetry

The observed baryon asymmetry may have been caused due to the decay of a heavy right handed neutrino. The value of the baryon asymmetry generated this way cannot be easily predicted as it requires the knowledge of parameters of the right handed neutrino sector. It is shown that left right symmetry can be profitably used for this purpose. One can relate baryon asymmetry to the neutrino oscillation parameters found in laboratory experiments. Different specific cases were considered and it was shown that the small angle or vacuum solution to the solar neutrino problem can lead to correct symmetry while the large angle solution needs some fine tuning in CP violating phases. This work was carried out with Dr. W. Rodejohann and Prof. E.A. Paschos of University of Dortmund, Germany.

(A. S. Joshipura)

Bi-Maximal Mixing and Bilinear R Violation

Theories with bilinear violation of R parity offer economic framework for generating neutrino masses and mixing. Possibility of understanding bi-maximal mixing between neutrinos was considered in a model independent manner. It was shown that one needs significant departure from the universal boundary conditions on soft supersymmetry breaking parameters in order to generate bi-maximal mixing. Constraints from rare lepton number violating processes play an important role in this analysis.

(A.S. Joshipura, R. Vaidya and S. Vempati)

Phenomenology of Pseudo-Dirac Neutrinos

We formulate general conditions on 3 x 3 neutrino mass matrices under which a degenerate pair of neutrinos at a high scale would split at low scale by radiative corrections involving only the standard model fields. This generalizes the original observations of Wolfenstein on pseudo Dirac neutrinos to three generations. A specific model involving partially broken discrete symmetry and solving the solar and atmospheric anomalies is proposed. The symmetry pattern of the model naturally generates two large angles one of which can account for the large angle MSW solution to the solar neutrino problem.

(A.S. Joshipura and S.D. Rindani)

Does LEP Prefer the NMSSM ?

The present searches for a supersymmetric Higgs Boson at Large Electron Positron (LEP) Collider severely constrain small values for the parameter β in the Minimal Supersymmetric Standard Model (MSSM). This leads to large fine-tuning within the parameters while requiring a correct electroweak symmetry breaking and problems with electroweak baryogenesis. It has been shown that in the low tanβ region the Next to Minimal Supersymmetric Standard Model (NMSSM) is in much better shape phenomenologically, since the physical Higgs boson masses are larger, the fine-tuning is less, and the electrweak phase transition is more strongly first order in the NMSSM, as compared to the MSSM. This work is done in collaboration with Profs. M. Bastero-Gil and S. F. King of Southampton University, U.K., C. Hugonie of Rutherford Laboratory, U.K. and D.P. Roy of Tata Institute of Fundamental Research, Mumbai.

(S. Vempati)

Nonperturbative Dynamical Properties at Finite Temperature and Densities

We have used nonperurbative variational methods in strong interaction physics dealing basically with *static* properties with nontrivial vacuum structure. We next study some *dynamic* properties at finite temperature and densities using variational methods. In particular we consider temporal correlation functions of hadronic currents at finite temperatures. The interesting information on hadronic states is then encoded in the spectral functions of these correlators. Currently available results from ab-initio lattice calculations show significant changes in the behaviour of temporal correlations at high temperature plasma. It is seen that at least close to T_C, the correlation functions clearly deviate from those from freely propagating quarks. Thus it is desirable to explore the possibility of alternative nonperturbative calculations at finite temperature to understand how far the temporal correlation functions carry information about existence or nonexistence of bound states or resonances in the plasma phase. This work is being pursued in collaboration with Amrita Mishra.

(H. Mishra and J.C. Parikh)

QCD Sum Rules at Finite Densities and Properties of Nucleon at Finite Temperature and Densities

Relativistic phenomenological models of nuclear physics - the quantum hadrodynamics describes successfully many nuclear physics problems, in particular, the saturation properties of nuclear matter and spectroscopy of nuclei. The scalar and vector meson exchange here give rise to attraction and repulsion respectively which leads to a saturation of nuclear matter. These contributions are large (several hundred MeV) and cancelling in nature and give rise to the binding energy/nucleon as 15 MeV at the saturation density. However, despite the appeal of phenomenology it has not been clear how this physics might be motivated from the fundamental theory of strong interactions - namely QCD. QCD sum rule techniques is being used to relate the nucleon self energies to quark and gluon condensates at finite densities. We calculate the phenomenological side of the sum rule taking into account the nucleon pole as well as absorptive part by considering definite intermediate states with Nπ, Nρ, Nω and Nϕ states. The reason for considering heavy states as above lies on the fact that they contribute singularities not only for $q_0^2 > (m_N + M_\rho)^2$ but also for $q_0^2 < (m_N - m_\rho)^2$ - a peculiarity of in-medium processes. The spectral side of the sum rules has already been evaluated and the QCD side of the sum rule is being calculated. This work is being pursued in collaboration with Samir Mallik (Calcutta) and J. Pashupathy (Bangalore).

(H. Mishra)

Vacuum Structure of Chiral Symmetry Breaking and Low Energy Hadron Properties

Although QCD is accepted as the theory of strong interaction physics, at present no reliable method is known to understand hadron physics, particularly, in the low energy regime where it becomes nonperturbative. The basic difficulty appears to be an understanding of the ground state properties of QCD or its vacuum structure which plays an important role for the related physics. We consider here a phenomenological approach for the determination of vacuum structure for chiral symmetry breaking. With a four compo-

nent structure for vacuum realignment for chiral symmetry breaking in the perturbative basis, we show here that through experimentally measurable quantities, we can determine (i) the four component quark field operators (ii) the wave functions for the corresponding Goldstone modes, (iii) the masses of approximate Goldstone modes and, (iv) a scheme for hadron spectroscopy which is similar to determining pion mass for approximate chiral symmetry breaking. The calculations for meson spectroscopy and estimation of certain decay widths using minimal coupling for electromagnetic interactions as driven by the strong interactions are in progress. This work is being pursued in collaboration with S.P. Misra (Bhubaneswar) and Amruta Mishra.

(H. Mishra)

Study of Weakly Interacting Particles using Laser Optics

Light by light scattering amplitudes depend upon the presence of virtual particles of low mass like axions and neutrinos. The optical rotation of laser beams propagating through strong magnetic fields can be used to investigate the properties of light weakly interacting particles. This work is carried out in collaboration with Drs. Uma Mahanta, Palash Pal and Jose Nieves.

(S. Mohanty)

Pair Production in Variable Electromagnetic Fields

Extension of the Schwinger method to study pair production in external fields which are not constant in spacetime is an interesting theoretical problem. It has application in accelerator experiments where intense lasers are collided with high energy photons, and in the strong electromagntic and color fields produced in heavy ion collisions. This work is carried out in collaboration with Prof. E. Masso and Prof. A. Grifols.

(S. Mohanty)

Neutrino Oscillation in Muon Colliders

In a muon collider the scattering process with a near shell neutrino is a dominant process. If neutrinos have non-zero masses then the cross section of this process depends upon the neutrino mass differences and the mixing angles. A theoretical calculation of neutrino mass dependence of this cross section can provide a new way of studying neutrino masses. This work is carried out in collaboration with Prof. W. Grimus and P. Stockinger.

(S. Mohanty)

Transverse Modes and Chaos in Classical SU(2) Yang-Mills Plasma

A nonperturbative treatment of the dynamics of purely transverse modes in a classical SU(2) Yang-Mills plasma is carried out. It is found that the equations governing the evolution of transverse modes are similar to the equations for longitudinal modes obtained by Bhatt et al. We have solved the equations approximately using multiple time scale method. It is observed that in the parameter regime where multiple time scale analysis is valid (when the non-abelian coupling terms are small), a new non-abelian mode appears modulating the frequency of the usual abelian mode. As the non-abelian coupling strength is increased, both frequency and amplitude modulation of the abelian mode is seen. For very large values of non-abelian coupling, chaotic behaviour sets in. This work was done in collaboration with Dr. Sudip Sen Gupta and Prof. Predhiman K. Kaw of Institute for Plasma Reserarch, Bhat, Gandhinagar.

(Jitendra C. Parikh)

Inflationary Baryogenesis

We explore the possibility of creating the matter-antimatter asymmetry of the universe during inflation and reheating due to the decay of a field associated with the inflation in the early universe. CP violation is attained by assuming that this field is complex with a phase that varies as the inflation evolves. We consider chaotic and natural inflation scenarios. In the former case, the complex decaying field is the inflation itself and, in the latter case, the phase of the complex field is the inflation. We calculate the asymmetry produced using the Bogolyubov formalism that relates annihilation and creation operators at late time to the annihilation and creation operators at early time. This work was

carried out with Dr. D. V. Nanopoulos of Texas A & M University, USA.

(Raghavan Rangarajan)

Baryon Number Violation in Particle Decays

It is well known that to obtain a matter-antimatter asymmetry through the decays of heavy particles in the early universe one must consider the interference between lowest order or *tree level* Feynman diagrams and higher order or *loop* diagrams. Furthermore, some intermediate particles in the loop diagrams must go *on shell* for the net asymmetry to be non-zero. It has been argued in the past that a further requirement is that one must consider loop diagrams that contain more than one baryon number violating coupling. In this report we argue that the requirement with regard to baryon number violating couplings in loop diagrams is that the interaction between the intermediate particles and the final particles should correspond to a net change in baryon number and that this can be satisfied even if the loop diagram contains only one baryon number violating coupling. This work is carried out with Dr. Rathin Adhikari of Calcutta University.

(Raghavan Rangarajan)

Decay-Lepton Angular Distributions in $e^+e^- \to t\bar{t}$ *to O(a_s) in the Soft-Gluon Approximation*

While the top quark has been discovered a few years ago, detailed properties of the top quark will have to await the construction of a linear e^+e^- collider. Polarization of top quarks can give useful information about its couplings. It is important to predict angular distributions of top decay products at such a collider, in order to get a handle on the polarization. Order-α_s QCD corrections in the soft-gluon approximation to angular distributions of decay charged leptons in the process $e^+e^- \to t\bar{t}$, followed by semi-leptonic decay of t or $\bar{t}$, are obtained in the e^+e^- centre-of-mass frame. As compared to distributions in the top rest frame, these have the advantage that they would allow direct comparison with experiment without the need to reconstruct the top rest frame or a spin quantization axis. Analytic expressions for the distribution in the charged-lepton polar angle and triple distribution in the polar angle of t and polar and azimuthal angles of the lepton are obtained. Numerical values are studied for $\sqrt{s} = 400$ GeV, 800 GeV and 1500 GeV.

(S.D. Rindani)

Neutrino Masses and Baryogenesis

Recently evidence for a non-zero neutrino mass has been found, which has many implications in particle physics. We have established a direct relationship between the smallness of the neutrino mass and an important question in cosmology, why there are more matter in the universe compared to the antimatter. Without this small excess of matter, we could not have survived the annihilation catastrophie. We have established a direct relation between this question of our existence and the neutrino mass. While we have earlier shown that some models of neutrino masses can explain this baryon asymmetry of the universe in a natural way, some other models of neutrino masses are ruled out since they erase this baryon asymmetry. We have now made a general analysis of this question of erasure of the baryon asymmetry of the universe taking into account of the evolution of the vacuum expectation value of the Higgs field and found that in some cases the results are modified by as high as 3 orders of magnitude. This work was done in collaboration with S. Kolb and H.V. Klapdor-Kleingrothaus of the Max-Planck-Institute fur Kernphysik, Heidelberg.

(Utpal Sarkar)

New Physics from Extra Dimensions

Our present knowledge of particles and their interactions is limited by the energy of the accelerators. So we have to rely on theoretical motivations to entend the theory beyond the standard model of the strong and the electroweak interactions. These interactions could be unified to a higher theory and with gravity only at a very high scale, which is not accessible in the next generation accelerators. Recently a new possibility has emerged, in which gravity propagates in some extra

dimension, in which ordinary particles can not enter. This theory predicts all new physics within the reach of the next generation accelerators. Gravity gets unified with all other interactions at around a few TeV. Since this idea can be verified soon, lots of activity has started in this field. We proposed a new scenario of neutrino masses with a Higgs triplet in a theory of large extra dimensions. Lepton number violation takes place in a distant brane, which acts as the source of a very small coupling in our brane, which can then explain the smallness of the neutrino mass. Small realistic Majorana neutrino masses are naturally obtained with the fundamental scale of about a TeV, foretelling the possible discovery of the triplet Higgs scalar at future colliders. If these events are observed, this model and also the existence of the large extra dimensions will be verified. This will mean we can see deviations from Newtons law at small distances. There are many other interesting predictions of this idea, which are being pursued. This work was done with E.Ma of the University of California at Riverside, USA and M. Raidal of CERN, Switzerland.

(Utpal Sarkar)

Nuclear Physics

Transition Strengths and Quantum Chaos in Large pf and sd-pf Shell-Model Spaces

Shell-model results for the electric quadrupole, magnetic dipole and Gamow-Teller transition strength sums and occupation numbers are calculated and compared to the last year reported predictions of the EGOE(k) (embedded Gaussian orthogonal ensemble of random matrices generated by k-body interactions; k=2 for atomic nuclei) model. In order to get good statistics and to check the results in different configuration spaces, the study has been performed for ^{46}Ti, ^{48}Sc and ^{52}Sc in the *pf* shell and ^{36}Mg, ^{36}Na and ^{36}Ne in the *sd-pf* shell-model space, involving dimensions from about 1000 to 8000. Using these extensive calculations, it is established that *transition strength sums* can be considered as a *new statistic* (just as the traditional nearest neighbour spacing distribution and the Dyson-Mehta Δ_3 statistic) able to distinguish between regular and chaotic motion in interacting particle systems. Moreover it is established that the EGOE (but not the GOE) provides the good description of the shell-model strength sums in the chaotic domain. To get these results, studied is the behaviour of strength sums in *order to chaos transitions* in ^{52}Sc and ^{36}Mg generated by means of a family of Hamiltonians $H(\lambda) = h(1) + \lambda V(2)$, built from realistic one and two-body interactions. Using the Gaussian forms involved in the EGOE strength sums, derived is a prescription for finding the threshold excitation energy for the onset of chaos. This work is done with R. Sahu (Berhampur), Dr. K. Kar (Calcutta), and Profs. J.M.G. Gomez and J. Retamosa (Madrid, Spain).

(V.K.B. Kota)

Average-Fluctuation Separations in Energy Levels in Dense Interacting Boson Systems

Unlike the case with finite interacting fermion systems, there are very few investigations so far for general finite interacting boson systems for their statistical properties. For example employing the interacting boson model (IBM) of atomic nuclei and a simple symmetrized two coupled rotors model, the nature of level fluctuations, occupation numbers, the probability for the occurrence of ordered structures (vibrations and rotations) in nuclei etc. are investigated in boson systems recently. In addition, many years back PRL scientists established that the state density for dense boson systems is a Gaussian. Going beyond these and employing the two-body random matrix ensemble EGOE(2), it is demonstrated for the first time this year by PRL scientists, that finite interacting boson systems in the dense limit (this limit is absent in fermion systems) exhibit average-fluctuation separations with the smoothed state density being a Gaussian (with corrections) and the fluctuations are of GOE type. This is accomplished by using the normal mode decomposition of the EGOE state density and analyzing both numerically (employing a system 10 interacting bosons in 5 single particle states with matrix dimension 1001) and analytically (here the so called binary correlation method is used) the variance of the level motion in the ensemble. This work is done with Prof. V. Potbhare (MS University, Vadodara).

(V.K.B. Kota)

Structure of Wavefunctions in (1+2)-body Random Matrix Ensembles

Random matrix ensembles (EGOE(1+2)) defined by a mean-field one-body plus a chaos generating random two-body interaction $\{H(\lambda)\}=h(1)+\lambda,\{V(2)\}$, predict for wavefunctions, in the chaotic domain, an essentially one parameter Gaussian forms for the energy dependence of the number of principal components NPC and the localization length l_H (defined by information entropy), which are two important measures of chaos in finite interacting many particle systems; the NPC and l_H are for the wavefunctions with energy E expanded in terms of the mean-field basis states $|k>$ with energy E_k. The EGOE(1+2) results are based on: (i) the Gaussian form for strength functions and the bivariate Gaussian form for the joint density in (E,E_k) (the former being a conditional density of the latter) which are valid in the chaotic domain (defined by a critical λ value as described in the last year report); (ii) there is average-fluctuation separations (with little communication between the two) in energy levels and strengths with local strength fluctuations following the Porter-Thomas law; (iii) there is a significant unitary group decomposition of the Hamiltonian. Numerical embedded ensemble calculations, nuclear shell model results (in *sd* and *pf* spaces) and the results of a EGOE(2) model with spin (EGOE(2)-S), for NPC and l_H, are compared with the theory. These analysis (**Fig. 2.1**) clearly point out that for realistic finite interacting many particle systems, in the chaotic domain, wavefunction structure is given by (1+2)-body embedded random matrix ensembles. This work is done with Dr. R. Sahu (Berhampur).

(V.K.B. Kota)

Plasma Physics

Longitudinal and Transverse Waves in Dusty Crystals

After the experimental observations of dusty crystals in laboratory there has been flurry of activities in studying the dusty crystals. Recently longitudinal and transverse shear waves have been observed in the dusty crystal experiments. Using the method of condensed matter physics we have developed a hydrodynamical model to describe low frequency response of dusty crystals. We have found, using the model, that logitudinal and transverse shear waves can be well described by the model. We have also studied gravity-acoustic modes in the dusty crystal using our model.

(J.R. Bhatt)

Rayleigh-Taylor Type Instability in a Weakly Ionized Plasma under Zero Gravity Condition

The role of neutral dynamics in a weakly ionized plasma is being studied for the generation of plasma instabilities under different plasma environments. It is found that a Rayleigh-Taylor type instability can be generated in an inhomogeneous medium where the effect of gravity can be neglected. The role of gravity may be played by the drag force between neutrals and ions with appropriate collisions and relative velocities between neutrals and ions. This has potential to explain some of the observations of plasma irregularities in the cometary plasma environment where the neutral population is substantial and satisfies other conditions for the generation of these instabilities. This work is done in collaboration with Dr. A.A. Shaikh of C.U. Shah Science College, Ahmedabad.

(A.C. Das)

Electrostatic Modes in Dense Dusty Plasmas with High Fugacity : Numerical Results

The existence of ultra low-frequency wave modes in dusty plasmas has been investigated over a wide range of dust fugacity [$f \equiv 4\pi n_{d0}\lambda_D^2 R$, where n_{do} is the dust number density, λ_D is the Debye length and R is the radius] and the grain charging frequency (ω_I) by numerically solving the dispersion relation obtained from the kinetic theory. In the long wavelength limit and for frequencies $\omega << \omega_I$, the dispersion curves obtained from the numerical solutions of the real as well as the complex (kinetic) dispersion relations agree well with the analytical expressions derived from the fluid and the kinetic theories, and are thus identified with the ultra

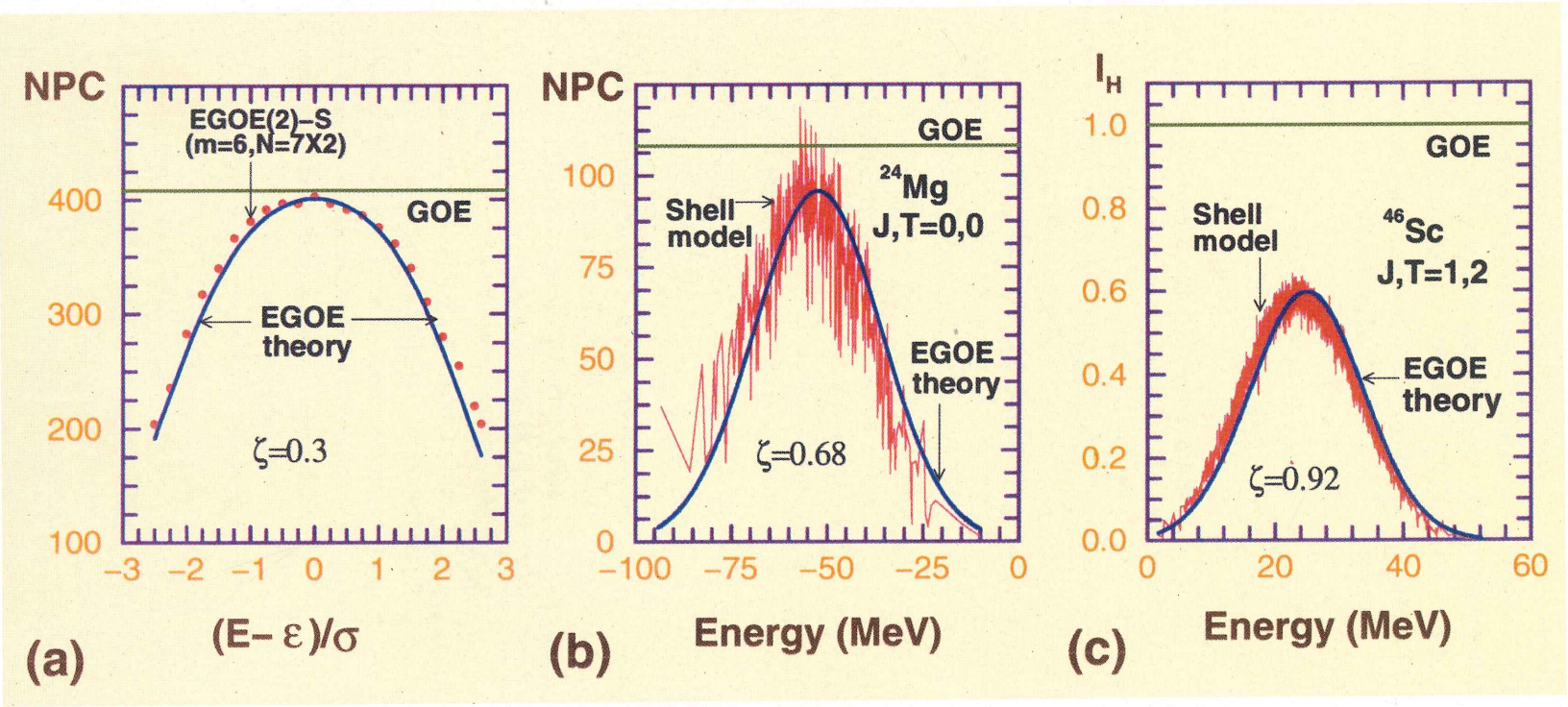


Fig. 2.1 (a) Number of principal components NPC for the EGOE(2)-S model with 6 particles in 7 spin 1/2 levels with total spin S=0. (b) Shell model results for the (sd) shell nucleus ^{24}Mg for NPC. (c) Shell model results for the pf shell nucleus ^{46}Sc for the localization length l_H In the figures a-c, the model results are compared with the results from the EGOE(1+2) and GOE formulas. Note the wide range of ζ values covered by the three model calculations. Finally, in (a) the parameters ε and σ are the spectrum centriod and variance and in (b) and (c), J and T are the angular momentum and isospin of the nuclear levels.

low - frequency electrostatic dust modes, namely, the Dust - Acoustic Wave (DAW), the Dust Charge - Density Wave (DCDW) and the Dust - Coulomb Wave (DCW). In particular, the analytical scaling between the phase speeds of the DCWs and the DAWs predicted from theoretical considerations, namely, $(\omega/k)_{DCW}=(\omega/k)_{DAW}/\sqrt{f\delta}$ (where δ is the ratio of the charging frequencies) is in excellent agreement with the numerical results. A simple physical picture of the DCWs has been proposed by defining an effective pressure called *Coulomb pressure* as $P_c \equiv n_{d0}q_{d0}^2 / R$, q_{do} is the grain surface charge. Accordingly, the DCW dispersion relation is given, in the lowest order, by $(\omega / k)_{DCW}=\sqrt{P_c} / \rho_d\delta$, where $\rho_d \equiv n_{d0}m_d$ is the dust mass density. Thus, the DCWs which are driven by the Coulomb pressure can be considered as the electrostatic analogue of the Alfvén or magnetoacoustic waves which are driven by the magnetic field pressure. For the frequency regime $\omega >> \omega_i$, the numerical results confirm the existence of only the DAWs, while the DCWs are absent as predicted by the fluid and the kinetic theories. The wave damping rates due to the charge fluctuations as well as the wave-particle interactions (Landau type) have been numerically computed and compared with the analytical results. For the tenuous as well as the dilute regimes, there is good agreement between the numerical and the analytical results at small wavenumbers. However, at larger wavenumbers and for the dense regime, the damping rates are underestimated by the theoretical expressions obtained under suitable approximations. Some comments on the sources for these differences have also been presented.

(N.N. Rao)

Nonlinear Waves in Dense Dusty Plasmas with High Fugacity

Nonlinear propagation of small, but finite, amplitude electrostatic dust waves has been investigated in the low as well as high fugacity regimes by deriving the corresponding Boussinesq equation which, for uni-directional propagation, reduces to the Korteweg - de Vries equation. The dust-acoustic wave (DAW) solitons are shown to correspond to the tenuous (low fugacity) dusty plasmas, while in the dense (high fugacity) regime the solitons are associated with the dust-Coulomb waves (DCWs). Unlike the DAW solitons which are (dust) density compressional and supersonic, the DCW solitons are (dust) density rarefactive and propagate with super-Coulombic speeds. This work was carried out in collaboration with Prof. P.K. Shukla.

(N.N. Rao)

Electrostatic Surface Waves in Dense Dusty Plasmas with High Fugacity

The propagation of electrostatic surface modes on a thin dusty plasma slab has been investigated in different dust fugacity regimes. For wave frequencies much smaller than the grain charging frequency and for long wavelengths, it is shown that dusty plasmas support three different types of surface modes, namely, the Dust-Acoustic Surface Wave (DASW), the Dust Charge-Density Surface Wave (DCDSW) and the Dust-Coulomb Surface Wave (DCSW) which exist, respectively, in the low fugacity (tenuous), medium fugacity (dilute) and high fugacity (dense) regimes. In the short wavelength range, there exists a new kind of surface mode called *Dusty Plasma Surface Wave* (DPSW) which has no counterparts in the volume modes. On the other hand, for frequencies much larger than the grain charging frequency, the DASWs exist also in the dilute regime, while the DCSWs are found to be absent. In the short wavelength limit, the DPSWs continue to exist even in the high frequency range. Explicit dispersion relations as well the damping rates due to the grain charge fluctuations are derived in each case. The results obtained for the various surface modes are compared with those for the case of volume modes. This work was carried out in collaboration with Prof. L. Stenflo and Prof. P.K. Shukla.

(N.N. Rao)

Electrostatic Thermal Modes in Dusty Plasmas

It is well-known that the presence of trapped particles significantly modifies wave propagation characteristics in collisionless electron-ion plasmas. However,

very little work has been carried out on the effects of trapped particles on dusty particles. Wave propagation in the presence of resonant particles for phase speeds near the thermal range is intrinsically nonlinear. On the other hand, the standard linearized Vlasov theory shows that the dust-acoustic waves (DAWs) would be highly Landau damped for propagation in the dust thermal range. We consider the effect of trapped dust particles on the propagation of electrostatic dust modes in the dust thermal speed range. We find that there exist a new class of stationary, **nonlinear** undamped electrostatic acoustic modes over a wide range of dust fugacity. These modes arise due to the distorted distribution of dust particles trapped in the wave field. They propagate below or above the dust-thermal velocity depending on the deficit or the surplus of dust particles trapped in the trough of the wave potential. It must be noted that these modes are *intrinsically nonlinear*, can not be studied using the standard linear theory. This work was carried out in collaboration with Prof. H. Schamel and Prof. Nilakshi Das.

(N.N. Rao)

Grain Charge, Scaling Laws and Wave Modes in Dense Dusty Plasmas with High Fugacity

Physical characteristics in dusty plasmas are crucially governed by grain charge, which can be significantly affected by three factors: (i) The presence of near neighbour grains typically leads to a decrease in the grain charge; (ii) The grain capacitance in general, is modified by the presence of other grains; (iii) For large grain sizes, the usual assumption of permeable grains is inapplicable, and the plasma should be excluded from the physical volume occupied by the individual grains. To our knowledge, there do not exist scaling laws for grain charge which incorporate contributions from all these three factors. In this work, we derive scaling laws for grain charge as a function of fugacity by self-consistently including contributions due to near-neighbor effects, generalized grain capacitance and finite grain size. In the process, we revise the concept of fugacity introduced earlier, and propose a more general definition which explicitly incorporates correctly the contributions due to generalized capacitance and impermeable nature of the grains. A detailed analysis shows excellent agreement between the analytical scaling laws and the numerical solutions of exact coupled equations over a wide range of dust fugacity from tenuous to dense regimes. The effects of these contributions on wave propagation in dense dusty plasmas is illustrated by considering dust-acoustic (DAWs) and dust-Coulomb waves (DCWs).

(N.N. Rao)

Self-Similar Expansion of a Non-Ideal Dusty Plasma

The self-similar expansion into vacuum of a non-ideal dusty plasma filling the semi-infinite half space has been investigated. The non-ideal contributions arising from the dust species has been modelled by the van der Waals equation of state, while the electrons and the ions have been assumed to be ideal. The equations describing the self-similar expansion have been derived and solved numerically to obtain the expansion profiles. For the magnetized case, we assume the plasma to be frozen to the magnetic field, and derive basic equations using an effective two-fluid MHD model. The effect of the non-ideal contributions coming from the volume reduction coefficient (because of the finite size of the dust grains) and the inter-grain cohesive forces have been analyzed. It is shown that a non-ideal thermal plasma expands over a much larger distance than the isothermal ideal plasma. This work was carried out in collaboration with Prof. R. Bharuthram and Prof. S.R. Pillay.

(N.N. Rao)

The Grain Charging and the Dust Acoustic Wave Instability

The stability of the steady charging state of the assembly of the dust grains in a plasma is analysed using the equations of thermal energy balance with the grain charging terms for both the electron and ion species. The grains are taken to be immobile for the purpose of this analysis. Two limiting cases are analyzed (i) $f (\equiv 4\pi n_d \lambda_D^2 a) << 1$ and $f >> 1$ (n_d is the dust number density, λ_D plasma Debye length, and a, the grain ra-

dius). The steady grain charge state is found to be stable in the case f << 1, so that the steady state grain charge q_0 is unaffected. On the other hand, in the limit f >> 1, the state is found to be unstable provided $\gamma_q (\equiv q_0 e / aTe) < \frac{1}{2}(T_e - T_i)/T_e$ (T_e, T_i are electron and ion temperatures). A coherent charging of the dust grains results as a consequence of this instability until $\gamma_q \approx \frac{1}{2}(T_e - T_i)/T_i$ Next, by letting the grain charges be mobile, so that the perturbation of dust number density is nonzero, examined is the stability of the dust-acoustic wave (DAW). The DAW is found to be unstable, also in the f >> 1case, while stable in the f << 1. The instability of the DAW also implies a concomitant grain charge growth, which would again be of a coherent nature.

(R.K. Varma)

A Probability Amplitude Description of the Dynamics of Charged Particles in a Magnetic Field in the Macrodomain

The set of Schrödinger-like equations obtained earlier by PRL scientists for the charged particle dynamics in an inhomogeneous magnetic field in the macro-domain, are derived starting from the quantum-mechanic Schrödinger equation in its path integral representation. This derivation enables a generalization of the equations to include a curl-free vector potential in the Schrödinger-like equations. In view of the amplitude character of the latter equations which now descends directly from that of the quantum-mechanic Schrödinger equation, they now predict, the existence, in the macro-domain of all such phenomena which are characteristic of a probability amplitude theory, e.g. the interference, and the observation of a curl-free vector *a la* Aharonov-Bohm. A discrete energy structure, predicted as interference maxima and minima has already been observed by PRL scientists. A prediction is now made for the observability of a curl-free vector potential in the macro-domain, in the context of the present problem.

(R.K. Varma)

Observation of Beat Structure in the Transmission of Electrons along a Magnetic Field in the Classical Mechanical Domain

A discrete energy structure in the transmission of electrons along magnetic field was observed earlier by PRL scientists pointing to the existence of *allowed* and *forbidden* states in the nonquantal macrodomain. The interpeak separations in the discrete structure is determined by both the strength of the magnetic field and the distance between the electron gun and the detector plate, with a grid close by in front of it. The distance determines the *frequency* of variation of plate current with the electron energy or more appropriately inverse electron parallel velocity. We report here the existence of a beat structure modulating the already observed discrete energy structure, which is determined by the distance between the plate and the grid. Since the frequency of variation of the transmitted current as recorded on the plate is determined by the gun-plate distance, the difference between the two lengths in the set up mentioned above are shown to determine the beat frequency, as in the case of other wave phenomena. A wave algorithm based on the Schrödinger-like formalism is presented which describes all these observations.

(R.K. Varma, A.M. Punithavelu and S.B. Banerjee)

Application of Chaotic Dynamics to Communications through Synchronization

Various methods of communication based on synchronization of two identical chaotic systems are studied in great detail. The method that uses the synchronization of active-passive decomposition of a chaotic system is found to be good. In our computer simulation we have applied the method to communicate three computer generated and two experimental time series signals using different chaotic systems and their combinations. The merits of communication using this method are studied in terms of shape of the transmitted signal, extent of the masking of the signal, errors in the recovered signal and spectra of original and recovered signals. In general, it is found that masking of the signal is quite effective and the accuracy of the recovered signal is very high. It is, however, observed that the signal of short length consisting of sharp kinks in the data requires additional smoothing to be masked effectively. Combinations of chaotic systems are used to generate hyperchaotic transmitted signal to carry the information signal. It is expected that they would be difficult to decode and hence would lead to more secure communications but unfortunately they also have relatively low accuracy of the recovered signal. We have also examined the effect of additive noise and variation of parameters of chaotic systems on the accuracy of the recovered signal.

(R. E. Amtritkar , D. R. Kulkarni and V. B. Sheorey)

Evidence of Levy Stable Process in Tokamak Edge Turbulence

The wavelet analysis of floating potential fluctuation in the edge plasma of ADITYA tokamak indicates that the probability distribution function (PDFs) at different scales collapse to a single PDF in a range of scales. The PDF has a pronounced non-Gaussian feature with kurtosis, $K = 1.0 \pm 0.1$. This has encouraged us to look for other evidences of scaling properties. We have carried out the R/S range analysis of fluctuation data which indicates the presence of scaling in the time range 10-200μs. The estimated value of the Hurst parameter, $H = 0.9$ indicates long-range time correlation. Another evidence of long-range correlation is the Levy distribution. When we fit the Levy distribution to our data it is observed that the PDF of sum of n potential fluctuations converge to a Levy distribution of parameter, $\alpha = 1.111$ for $n \leq 40$ whereas for larger n the PDF converges to a Gaussian distribution. This provides evidence for self-similarity in fluctuation data. The structure function analysis further shows that the data is monofractal and can be modelled by additive Levy processes. The results indicate that the small scale fluctuations are super-diffusive whereas the large scale fluctuations are diffusive. This work was done in collaboration with Dr. R. Jha and Prof. P. K. Kaw of Institute of Plasma Research.

(D. R. Kulkarni and J. C. Parikh)

Algebraic Approach to the Study of Nonlinear Integrable Models

The classical and the quantal problem of a particle interacting in one-dimension with an external time-dependent quadratic potential and a constant inverse square potential was studied from the Lie-algebraic point of view. The integrability of this system was established by evaluating the exact invariant closely related to the Lewis and Riesenfeld invariant for the time-dependent harmonic oscillator. We studied extensively the special and interesting case of a kicked quadratic potential from which we derived a new integrable, nonlinear, area preserving, two-dimensional map which may, for instance, be used in numerical algorithms that integrate the Calogero-Sutherland-Moser Hamiltonian. The dynamics, both classical and quantal, was studied via the time-evolution operator which we evaluated using a recent method of integrating the quantum Liouville-Bloch equations. The results show the exact one-to-one correspondence between the classical and the quantal dynamics. Our analysis also sheds light on the connection between properties of the SU(1,1) algebra and that of simple dynamical systems.

(J. N. Bandyopadhyaya, A. Lakshminarayan and V. B. Sheorey)

Quantum Dynamical Localization in Non-KAM Systems

A two-parameter non-KAM generalization of the kicked rotor, which can be seen as the *standard map* of particles subjected to both smooth and hard potentials was studied. The virtue of the generalization lies in the introduction of an extra parameter R which is the ratio of two length scales, namely the well width and the field wavelength. If R is a non-integer the dynamics is discontinuous and non-KAM. We have explored the role of R in controlling the localization properties of chaotic eigenstates. In particular the connection between classical diffusion and localization was found to generalize reasonably well. In unbounded chaotic systems such as these, while the nearest neighbour spacing distribution of the eigenvalues is less sensitive to the nature of the classical dynamics, the distribution of participation ratios of the eigenstates proves to be a sensitive measure; in the chaotic regimes the latter being lognormal. We find that the tails of the well converged localized states are exponentially localized despite the discontinuous dynamics while the bulk part shows fluctuations that tend to be closer to Random Matrix Theory predictions. Time evolving states show considerable R dependence and tuning R to enhance classical diffusion can lead to significantly larger quantum diffusion for the same field strengths, an effect that is potentially observable in present day experiments.

(R. Sankaranarayanan, A. Lakshminarayan and V. B. Sheorey)

Quantum Entanglement and Quantum Chaos

In this class of work we have explored the relationship between the uniquely quantum phenomenon of *entanglement*, measuring non-separability of states, and quantum chaos. Entanglement being a resource for various quantum information processing, including computation, needs to be fully understood. We showed that quantum entanglement was enhanced due to quantum chaos. We have uncovered scarring of Schmidt vectors and have shown how entanglement can be a useful characterization of quantum chaos. Models that are used in exploring these are higher dimensional symplectic maps, and coupled oscillators of various kinds.

(A. Lakshminarayan and J. N. Bandyopadhyaya)

Small World Networks

We have carried out the analytical and numerical treatment of a random walk on the family of small-world graphs. The average access time shows a crossover from the regular behavior with increasing distance from the starting point of the random walk. We introduce an *independent step approximation,* which enables us to obtain analytic results for the average access time. We observe a scaling relation for the average access time in the degree of the nodes. The behavior of average access time as a function of p, shows striking similarity with that of the *characteristic length* of the graph. This observation may have important applications in routing and switching in networks with large number of nodes.

(S. Pandit and R. E. Amritkar)

Matter Waves in the Macrodomain

The de Broglie matter waves with the wave length given by $\lambda = \hbar / mv$ are known to be typically in range of a few Angstrom, because essentially of the small value of $\hbar$. The question may be asked however, if matter can exhibit its wave aspect in macrodimensions as well, not in the sense of macroscopic correlated quantum systems such as superfluids or superconductors, but in the manner and spirit of de Broglie waves associated with single particle behaviour. We show here that it is indeed so possible. In fact, having already observed such a wave behaviour by PRL scientists, in the macrodomain for electrons propagating along with a magnetic field, with a wave length which is independent of $\hbar$ and typically in the range a few centimeters, it is shown that such a wave manifestation is not entirely peculiar to this system but is a generic property of composite bound systems in their highly excited internal states approaching the classical limit. The wave length of these new matter waves is shown to be related, not to the masses of these particles as in the case of de Broglie waves, but to the frequency associated with their internal state of excitation. This is an entirely new wave manifestation of matter not hitherto pointed out.

(R.K. Varma)

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

Theory of Electromagnetically Induced Waveguides

In recent years considerable progress has been made in achieving control of the optical properties of a medium. In particular, the control of the dispersive properties of a medium was demonstrated by producing an optically written waveguide in an atomic vapour. In the experiment, a weak Gaussian probe beam was tuned close to the rubidium D_2 line, while a strong doughnut shaped pump beam was tuned close to the rubidium D_1 line.

We develop an explanation of the waveguiding effect by using density matrix equations and propagation equations in slowly varying envelope approximation. Our work includes all coherence effects. Our numerical simulations for Doppler broadened systems are in excellent agreement with the experimental results and also show guiding behaviour at different positions inside the medium. This work was done in collaboration with R. Kapoor, Centre for Advanced Technology, Indore.

(G. S. Agarwal)

Wigner Representation of Laguerre-Gaussian Beams

The Wigner distribution function has come to play an ever increasing role in the description of both coherent and partially coherent beams and their passage through first-order systems. Since symmetric first-order systems are separable in Cartesian as well as in polar coordinates, both the Hermite-Gaussian (HG) and Laguerre-Gaussian (LG) modes turn up as eigenmodes of such systems. The Wigner function of a HG mode has been known since the early days of quantum mechanics and has a simple closed form expression in terms of Laguerre polynomials. However, the expression for the Wigner function of a LG mode has been obtained only recently and contains a complicated fourfold summation.

We use phase-space symmetry aspects of the Wigner representations to bring out the precise connection between the HG and LG classes of modes and finally obtain for the Wigner distribution of a generic LG mode a closed-form expression that is as compact as the one for HG modes. This work was done in collaboration with R. Simon, Institute of Mathematical Sciences, Chennai.

(G. S. Agarwal)

Reconstruction of the Wigner Transform of a Rotationally Symmetric Two-dimensional Beam

Rotationally invariant fully coherent beams are essentially one-dimensional in content in the sense that the field distribution is fully determined by the one-dimensional sample along a diagonal of the circularly symmetric field distribution in a transverse plane. We present the linear transform that reconstructs the four-dimensional Wigner distribution of the full two-dimensional beam from the two-dimensional Wigner distribution of the one-dimensional sample.

This work was done in collaboration with R. Simon, Institute of Mathematical Sciences, Chennai.

(G. S. Agarwal)

Quantum Interferences and the Question of Thermodynamic Equilibrium

We derive from first principles the dynamical equations for the interaction between a heat bath and a multilevel atom with some near-degenerate states. Such dynamical equations exhibit atomic coherence terms that arise from the interference of transition amplitudes. We address the question whether such equations lead to a steady state that is consistent with the thermodynamic equilibrium. We show that coherence affects the dynamics of the system, but the equilibrium conditions are still characterized by Boltzmann factors. We also show how an asymmetric treatment of spontaneous and stimulated processes could lead to a steady state that is at variance with the principles of thermodynamic equi-

librium. We show that such a steady state can be realized by pumping with broadband laser fields. Finally, we show that coherence in the dynamical equations can be probed via the spectrum of fluorescence.

(G. S. Agarwal and Sunish Menon)

A Knob for Changing Light Propagation from Subluminal to Superluminal

We study the propagation of a weak electromagnetic pulse through a Λ-system when the central frequency of the pulse is close to the atomic transition frequency. This pulse couples one arm of the Λ-system and a strong laser field couples the other arm. The lower metastable states of the atom are coupled by an additional EM field. An undistorted pulse propagation requires a stringent condition that the medium should be absorptionless when the pulse is near-resonance with the atomic transition. However, by properly selecting the parameters, we could achieve this condition. We show that the group velocity of the weak pulse can be controlled by suitably choosing the intensity of the control laser and the additional coupling field. We also demonstrate that such control can even lead to a knob for changing the velocity of propagation of the pulse from subluminal to superluminal.

(G. S. Agarwal, Tarak Nath Dey and Sunish Menon)

Super-classical Traversal of Ultra-cold Atoms through a Cavity

We examine the propagation of a Gaussian wave packet of an excited two-level atom through a high quality single mode cavity which is initially in vacuum state. We find that the atom-field interaction is equivalent to reflection and transmission of the wave packet through a quantum mechanical potential. This potential, which is induced by the vacuum field, can be termed as vacuum-induced potential. We calculate the passage time (phase time) for the wave packet to traverse the cavity. An important feature is that the phase time for traversal is less than the time needed for free space propagation. Thus the traversal of atom is faster through the cavity when compared with its propagation through the same distance in free space. We also find that the phase time can be negative for some sets of parameters. Negative phase time implies that the peak of the transmitted wave packet emerges out even before the peak of the incident wave packet enters the cavity. We label these features as super-classical traversal of ultra-cold atoms and view them as matter wave analogues of the super-luminal propagation of electromagnetic pulses through anamolous dispersive media.

(R. Arun and G. S. Agarwal)

Improving the Fidelity of Quantum Cloning by Field-induced Inhibition of the Unwanted Transition

A single-mode photon can be cloned by stimulated emission of an initially excited atom in V-configuration inside a two-mode cavity. However, the fidelity of this scheme is limited to its optimal value 5/6. We traced out that the source of this non-unity fidelity is the spontaneous decay of atom in the orthogonal mode. We investigated how this unwanted decay can be inhibited to increase the fidelity by using a coherent field. This field couples the excited states of the atom to a metastable state and cycles the atomic population through this state. We have made the cycling fields dependent on the states of the input qubit, so that all the states can be cloned equally well, by suitably choosing the coupling field parameters. Considering two atoms in the cavity, we found that the fidelity could be increased considerably for a long range of time. Also the fidelity, averaged over all the states of the input qubit for the one-atom cloner, can be improved by using the cycling fields.

(S. Dasgupta and G. S. Agarwal)

Anisotropic Vacuum-induced Interfernces in Decay Channels

Recently, considerable effort has been devoted to the question of vacuum induced coherence and interference effects arising from the decay of close lying energy levels. However, the very existence of the

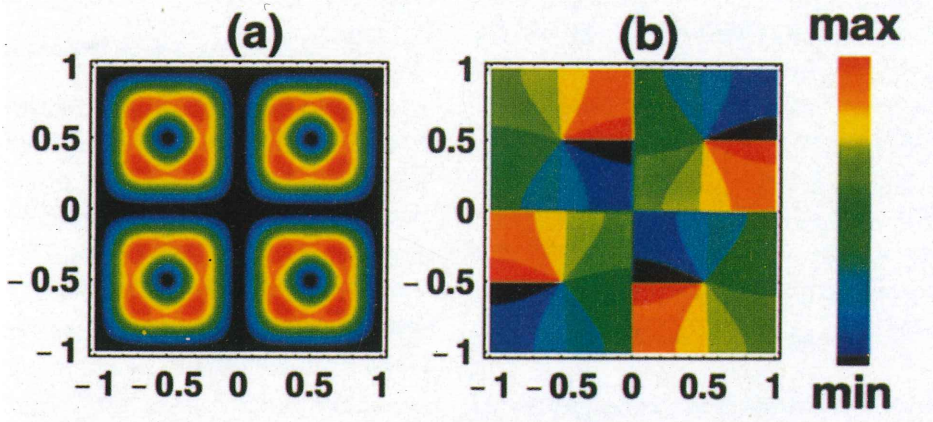


Fig. 4.1 Contour plots of the (a) transverse intensity and (b) phase profiles of a 2 x 2 array of optical vortices formed inside a multimode waveguide of square cross section.

interfernce effect depends on the validity of a very stringent condition, viz., the dipole matrix moments for two close lying states decaying to a common final state should be *non-orthogonal.* This last condition is really the bottleneck in the observation of the predicted new effects.

We propose a mechanism to overcome the problem of the orthogonality of the dipole moments. We suggest working in such situations where the vacuum of the electromagnetic field is *anisotropic*, so that the interference among decay channels can occur even if the corresponding dipole moments are orthogonal. This opens up the possibility of studying quantum interferences in a variety of new classes of systems.

(G. S. Agarwal)

Vacuum-induced Coherences in Radiatively Coupled Multilevel Systems

Previous studies of vacuum induced coherence (VIC) dealt with a *single* multilevel atom, or equivalently, with an ensemble of non-interacting multilevel atoms (e.g., very low density atomic gas systems). However, VIC in *coupled* atomic systems has remained unexplored.

We show that radiative coupling between two multilevel atoms having near-degenerate states can produce new interference effects in spontaneous emission. We explicitly demonstrate this possibility by considering two identical V systems each having a pair of transition dipole matrix elements that are orthogonal to each other. We discuss in detail the origin of new interference terms and their consequences. Such terms lead to the evolution of certain coherences and excitations that would not occur otherwise. The special choice of the orientation of the transition dipole matrix elements enables us to illustrate the significance of vacuum-induced coherence in multiatom multilevel systems. These coherences can be significant in energy transfer studies.

(G. S. Agarwal and A. K. Patnaik)

The Generation of Optical Vortices and Shape Preserving Vortex Arrays in Hollow Multimode Waveguides

We predict that by coherently combining appropriate sets of the modes of hollow square cross-section multimode step-index waveguides, individual optical vortices and shape preserving vortex arrays can be generated. The vortices formed in this manner have intensity and phase characteristics similar to those found in Laguerre- Gaussian beams (**Fig. 4.1**). The resulting vortex fields should be useful for holding, manipulating and imparting orbital angular momentum to atoms and

microscopic particles inside hollow waveguides. The advantage of realizing vortex fields in hollow waveguides is that the interaction lengths can be made much greater than in free-space. It is also possible to envisage hollow waveguide optical circuits formed on the surface of suitable substrates. These circuits can be used to realize multiple vortex beam configurations in which atoms can be held and manipulated. This work was done in collaboration with R. M. Jenkins, DERA, U. K and A. R. Davies, Royal Holloway, Univ. of London, U. K.

(J. Banerji)

Off Resonant Pumping for Transition from Continuous to Discrete Spectrum and Quantum Revivals in Systems in Coherent States

We show that in parametrically driven systems and (more generally) systems in coherent states, off-resonant pumping can cause a transition from a continuum energy spectrum of the system to a discrete one, and result in quantum revivals of the initial state. The mechanism responsible for quantum revivals in the present case is different from that in the non-linear wavepacket dynamics of systems such as Rydberg atoms. We interpret the reported phenomena as an optical analog of Bloch oscillations realized in Fock space and propose a feasible scheme for inducing Bloch oscillations in trapped ions.

(G. S. Agarwal and J. Banerji)

Optical Limiting Studies of Dye Doped Polymers

With the use of high power lasers in varied applications, search for optical limiting materials has become very important to protect the eyes and other sensors. These materials are based on the principle of reverse saturable absorption (RSA) when absorption cross section for excited state becomes more than the ground state. In such cases transmittance goes down as we increase the intensity.

We have prepared two dye doped polymer films - one an azo dye namely Disperse orange and another 4-[4-(Dimethylamino)styryl]-1-docosylpyridinium bromide by mold and press technique. For both the dyes Polymehtylmethacrylate (PMMA) has been chosen as a matrix because of its easy availability and easiness of processing. Using open aperture z-scan technique, we observe saturable absorption (SA) for disperse orange films at 532 nm with a 6 ns and 10 Hz Nd:YAG laser. The other dye also shows SA but near the focal spot of the z-scan set up, where the intensity is higher, it shows RSA. We are doing z-scan at other wavelengths (1064 nm and 600 nm) also where we expect RSA for both the films. Our expectation is based on the nature of their linear absorption spectra. This work is being carried out in collaboration with Prof. D.N. Rao, School of Physics, University of Hyderabad.

(R.P. Singh and P.S. Aithal)

Middle Atmosphere

Surface Ozone Chemistry at a Coastal Site

As a part of the surface ozone measurements in different environments, measurements of ozone and NO_x are made at a coastal site Thumba near Trivandrum jointly with Space Physics Laboratory, Trivandrum. These observations show day time photochemical buildup of ozone like at Ahmedabad and Gadanki. However, the average noon time ozone levels are within 20 to 30 ppbv which are lower than at Ahmedabad or Gadanki. Average night time ozone mixing ratios are about 8 ppbv. The afternoon decrease in ozone concentration is slower like at Gadanki, which is due to slower titration with NO. One interesting feature observed is the secondary peak in ozone concentration in the evening hours just when sea breeze changes to land breeze. Maximum ozone levels are observed to be during March possibly due to intense photochemical production since this is also the month of the highest temperature.

(Duli Chand, S.Venkataramani, K. S. Modh and Shyam Lal)

Vertical Distributions of Ozone and Water Vapor over Chennai

Measurements of ozone and water vapor are being made all over the Indian region as a part of the MOZAIC (**M**easurement of **Oz**one by **A**irbus **I**n service air**C**raft) programme being run by the European group. MOZAIC data of Ozone and water vapor from ground to 10 km, obtained at Chennai during 1996 to 1998 was analyzed at PRL. High ozone mixing ratios (in the range of 50-70 ppbv) are observed during May and June months above about 5 km. An interesting result is that low ozone values (20-40 ppbv) are observed even above 5 km during July to October period.

(Lokesh Sahu and Shyam Lal)

Modelling of Vertical Distributions of SF_6

There have been few measurements of the vertical distribution of SF_6 especially in the tropics, which have restricted the validation of vertical transport in two-dimensional (2D) global models. In an attempt to fill in this void, we have used the MPIC-PRL 2D model in a transient mode to compare the calculated vertical distributions of SF_6 with observations made by our group at PRL over a decade. The gross feature of the simulated vertical profiles compares well with the observations particularly in the tropics **(Fig. 5.1)**. Comparisons with UARS/HALOE CH_4 data show that the sharp vertical gradient above the tropopause and the extremely weak gradient above 25 km in the observations in India are due to the Quasi Biannual Oscillation (QBO). The QBO is not taken into account in the model dynamics but in average between its west and east phase

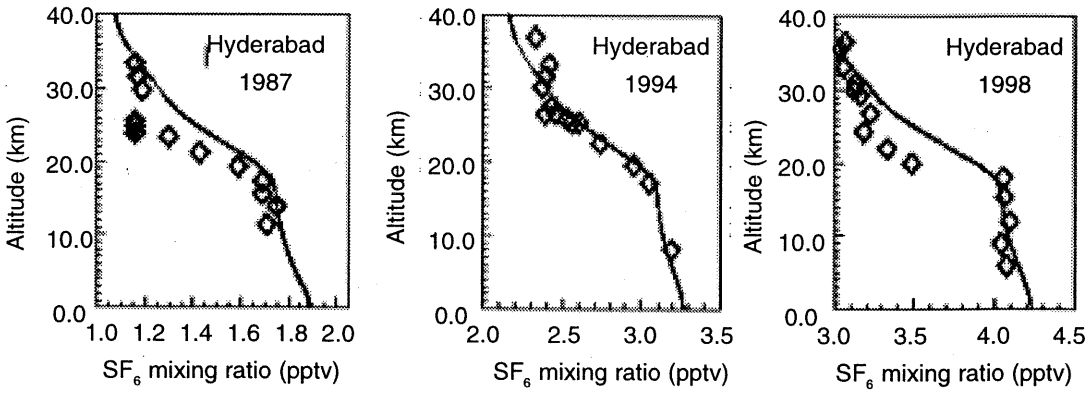


Fig. 5.1 Verticle distribution of SF_6 obtained from the balloon flights conducted in 1987 (a), 1994 (b) and 1998 (c) from Hyderabad (17°N (open symbols) compared with hte 2D model simulations (solid line)

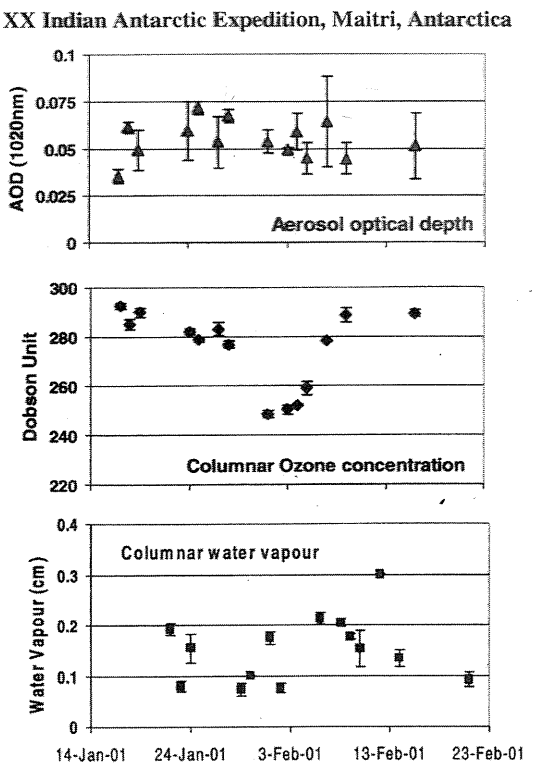


Fig. 5.2 Daily mean values of aerosol optical depth at 1020nm (top), column concentration of ozone (middle) and water vapor (bottom) measured at Maitri, Antarctica during XXth Antartic Expedition.

vertical profiles are represented well by the model. This work is being done jointly with the Max Planck Institute for Chemistry, Mainz, Germany.

(Varun Sheel and Shyam Lal)

Antarctic Aerosol Radiative Forcing Experiment

A pilot study to investigate the characteristics of aerosols present over the Antarctic region and to estimate their impact on the surface reaching solar radiation over this pristine site, an Antarctic Aerosol Radiative Forcing Experiment (AARFEX) was conducted by the Physical Research Laboratory during the 20th Indian Antarctic Expedition. Under the AARFEX a Quartz Crystal Microbalance (QCM), a Ground based UV Radiometer (GUV-R), a Hand held Sun Photometer and a Microtops Photometer were taken to Antarctica and installed at the Indian Antarctic Station Maitri (70.77° S, 11.73° E). QCM was used to measure the mass concentration and size distribution of Aerosol, GUV-Radiometer was used to measure the surface reaching global solar flux in the UV and visible part of the solar spectrum. The hand held Sun Photometer was used to measure the Aerosol Optical Depth at seven different wavelengths and Microtops photometer was used to measure the Ozone and water vapor column content in atmosphere. Expedition started on 29 December, 2000 and ended on 21 March, 2001. Optical observations were taken on cloud free days in January and February while the aerosol mass concentration and size distribution measurements were made continuously on all days **(Fig. 5.2).** Preliminary estimates of daily average vertical column values of aerosol optical depth at 1020-nm, ozone concentration (DU) and water vapor (cm) were made. Detailed analysis of the aerosol properties and radiative forcing is in progress.

(Harish Gadhavi and A. Jayaraman)

In-situ Measurements of Aerosol Characteristics over the Indian Ocean and Bay of Bengal

Aerosol optical depths, mass concentrations and size distributions were measured over the Arabian Sea and Indian Ocean in April 2000 on board *Sagar Kanya* during the IRS-P4 satellite data validation cruise. The aerosol optical depth, measured with a hand held Sun photometer, is found to be 0.75 at 500 nm over the Arabian Sea, very near to the coastline and it decreased to 0.25 in the Indian Ocean region. Aerosol optical depths show large variations in the smaller wavelength region when compared to the values in the higher wavelength region. Aerosol optical depths at 400 nm during the cruise varied from a high of about 1.2 to a low of 0.3, while in the 1000 nm region the values are in the range of 0.25-0.3. The aerosol size distribution obtained from the Quartz Crystal Microbalance cascade impactor is found to have three modes peaking at 0.05, 0.2 and 3μm radius. The aerosol optical depths track well the aerosol number density curves. To investigate the effect of wind driven aerosols over the Bay of Bengal, another cruise was conducted over the region during February 2001. Detailed analysis of the aerosol optical depth is in progress.

(S. Ramachandran, J.T. Vinchhi and A. Jayaraman)

Radiative Forcing due to Stratospheric Aerosols

Using an updated, comprehensive monthly-and-zonal mean spectral optical properties data set aerosol radiative forcing, stratospheric thermal and tropospheric climate response of SKYHI General Circulation Model to the Pinatubo volcanic eruption is being investigated. This study is performed by conducting an ensemble of eight 2-year SKYHI GCM integrations. Our calculations confirmed that the near IR solar forcing due to Pinatubo aerosols contributes substantially to the total stratospheric heating. Preliminary analysis of surface temperature anomalies in December-January-February 1991-92 show areas of warming of up to 2 K over Eurasia and cooling of 1 K over Middle East. A set of ensemble runs is in progress with the absorption due to aerosols turned off in the solar wavelength region to investigate the effects on the stratospheric and the tropospheric thermal response and the dynamics. Another set of ensemble runs are also in progress by introducing a perturbation larger than Pinatubo. The objective of this experiment is to investigate whether the radiative and dynamical effects due to volcanic aerosols respond linearly. This work is done in collaboration with Prof. V. Ramaswamy, Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey, USA.

(S. Ramachandran)

Diurnal Variation of Stratospheric Conductivity

The conductivity in troposphere and stratosphere is due to cosmic rays produced ionization. The conductivity is a function of ion density, atmospheric pressure (collision frequency) and ion mass. Balloon borne measurements of conductivity at float altitude over Hyderabad show diurnal variations of conductivity. The balloons were kept at float altitude for a period ranging from 6 to 12 hours in the altitude region of 30 to 35 km. We found that conductivity values show a semi-diurnal variation at stratospheric altitude. Since cosmic rays can not vary within a period of a day, such variations could be due to neutral dynamics. We know that pressure at stratospheric heights varies with a period of 12 hours. Hence the semi-diurnal variations observed in conductivity profile are related to pressure variation at these heights.

(S.P. Gupta)

Upper Atmosphere

Brightness Patterns in 777.4 nm Nightglow Emission

Multi-wavelength imaging observations taken from Kavalur (12.5°N, 78.8°E) using PRL's all sky imaging system showed for the first time the presence of brightness patterns (BP's) in 777.4 nm images. An increase in the intensity of airglow emission, by a factor of 2 to 5, over a large spatial extent (1000 km x 1000 km or more), in airglow images is termed as brightness pattern. Earlier observations had shown the appearance of BP's in 630 nm and 557.7 nm images only. Present observations from Kavalur detected the presence of brightness patterns in 777.4 nm images. The BP's showed differential behavior in 630 nm and 777.4 nm images. They initially appear in the northern part of the image and move equatorward and later spread in the entire field of view (FOV). These BP's were present in the FOV continuously for several hours. The relative brightness variation of these BP's shows a wave like pattern in 630 nm and 557.7 nm with a periodicity of about 80-90 minutes **(Fig. 5.3).**

(H. S. S. Sinha, P. K. Rajesh, R. N. Misra, N. Dutt, M. B. Dadhania, R. I. Patel and V. K. Parmar)

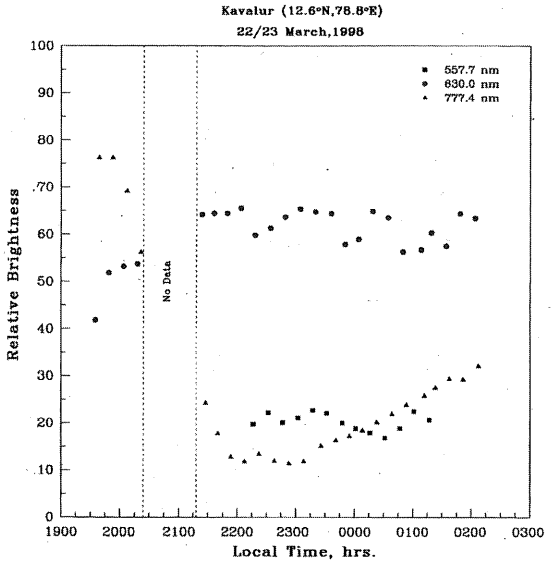


Fig. 5.3 Variation of the relative brightness of the airglow enhancements, in an area of 50x50 pixels, approximately located at the centre of the brightness pattern, on the night of 22/23 March, 1998.

Optical Imaging of Ionospheric Plasma Depletions from Kavalur

Optical imaging of plasma depletions at 630.0 nm, 777.4 nm and 557.7 nm from Kavalur have yielded new results. The east-west extent (l_{EW}) and inter-depletion distance (IDD) of plasma depletions show that there are three different types of plasma depletions, viz., (a) Type 1 having large l_{EW} (250-350 km) and IDD values in the range 125-300 km, (b) Type 2 having l_{EW} in the range 100-150 km and IDD values ranging between 50-150 km and (c) Type 3 having very small values of l_{EW} (40-100 km) as well as IDD (20-60 km). The IDD values are indicative of the scale sizes of the initial seeding agency, which are believed to be the gravity waves **(Fig. 5.4).** The small IDD values of Type 3 depletions show that the initial seed for the generation of these irregularities might have been provided by the electric fields produced by the gravity waves in the E region. Simultaneous appearance of plasma depletions with varying IDD, indicates the role of multiple agencies in generation of gravity waves of different scale sizes, which are responsible for the initial perturbation. The present observations show that, on an average, plasma depletions take about 2 hr 40 min to come to a fully developed stage after the onset of ESF.

(H. S. S. Sinha, P. K. Rajesh, R. N. Misra, N. Dutt, M. B. Dadhania, R. I. Patel and V. K. Parmar)

Effects of Magnetic Disturbance on 630, 557.7 and 777.4 nm Nightglow Emissions

Simultaneous appearance of plasma depletions in 630, 557.7 and 777.4 nm images : Optical imaging observations from Kavalur during a magnetically disturbed night, showed the simultaneous presence of plasma depletions at 630, 557.7 and 777.4 nm. The enhanced nightglow emissions at 557.7 nm and 777.4 nm occurred after a time interval of more than 6 hours after the commencement of magnetic disturbance. Enhancements in the 777.4 nm and 557.7 nm are interpreted in terms of increase of neutral densities in the low latitudes at the F region heights during a magnetic storm.. This time interval between the enhancement of 777.4 and 557.7 nm and the onset of the magnetic activity, matches with the cause-effect time required for such neutral density modifications in the low latitudes after the commencement of disturbances in the high latitudes.

Drift velocity of plasma depletions: slow drifting bubbles and drift reversal: Drift velocity of plasma depletions obtained from multi-wavelength imaging from Kavalur during March-April 1998 showed that 82% of the plasma depletions had drift velocities in the range 25-125 ms^{-1}. On one night, which was a magnetically disturbed night, the drift velocity was in the range of 0-25 ms^{-1} and at times depletions in the 630 nm images, appeared to be almost stationary. On the same

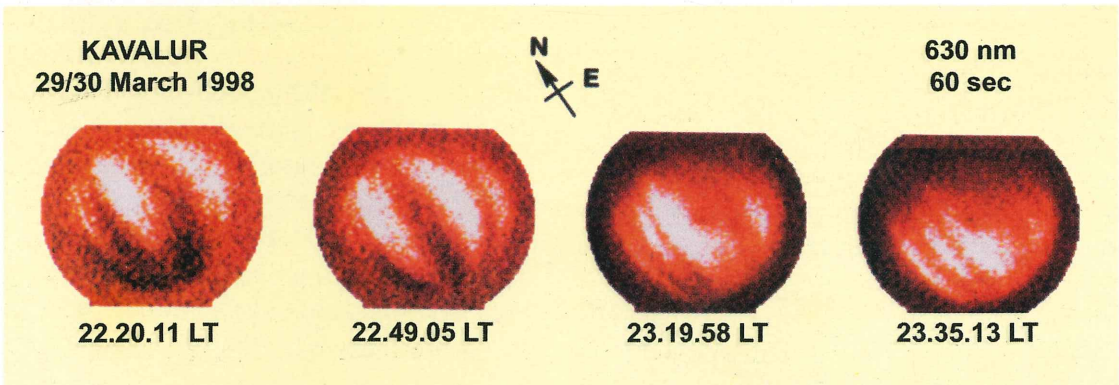


Fig. 5.4 Plasma depletions in 630nm images taken over Kavalur on the night of 29/30 March, 1998. The arrow points towards the geomagnetic north. Images at 22.20.11 and 22.49.05 LT are examples of Type 1 depletions and the remaining two refer to Type 3.

night, the depletions observed in 777.4 nm images showed a reversal in the drift direction from eastward to westward, for a time period of about 30 minutes and later showed normal eastward drift. At 2200 LT, which was the time of this drift reversal in the 777.4 nm images, depletions had almost zero eastward drift in 630 nm images. These unusual changes in the drift velocity of the depletions have been explained in terms of the penetration of disturbance in electric fields from high latitude to low latitude in the earlier part of the night and in the later part of the night, due to combined effect of changes in both electric fields and neutral winds.

(H. S. S. Sinha, P. K. Rajesh, R. N. Misra, N. Dutt, M. B. Dadhania, R. I. Patel and V. K. Parmar)

All Sky Optical Imaging of Plasma Depletions from the Crest of the Anomaly Region

A multi-wavelength imaging campaign was conducted during April 1999 from Mt. Abu (24.5° N, 72.7° E), which lies on the crest of the anomaly region. In addition to OI emissions (630 nm and 557.7 nm), OH (6,2) band (834.1 nm) was also used. Plasma depletions as well as brightness patterns could be clearly seen in 630 nm images. A few of 834.1 nm images also showed the presence of brightness patterns for about 30 minutes. Strong depletions were observed at 630 nm images taken on 14th April 1999. This was the first observation of plasma depletions from the anomaly region in the northern hemisphere. These observations show that the northern limit of plasma depletions is about 32° N, which when mapped back in terms of the altitude at the equator, corresponds to about 1300 km. Another important feature observed in these 630 nm images is the appearance of a brightness pattern. The BP appeared around the center of the image and did not show any movement with time, but its intensity showed a clear periodical variation. These BP's also, as in the case of Kavalur images, were present in the FOV for about 6-7 hours.

(H. S. S. Sinha, P. K. Rajesh, R. N. Misra, N. Dutt, M. B. Dadhania, R. I. Patel and V. K. Parmar)

Characterization of the Diurnal Patterns of OI 630.0 nm Dayglow Intensity Variations Measured from the Crest Region of Equatorial Ionization Anomaly

Continuous measurements of OI 630.0 nm dayglow from Mt. Abu (24.5°N, 72.7°E), a station in the vicinity of the northern crest of equatorial ionization anomaly (EIA), by means of the ground-based dayglow photometer (DGP) unravel systematic trends in the diurnal patterns of dayglow intensity variations corresponding to specific geophysical conditions. The investigation was carried out using the dayglow data, the ground-based magnetometer data from Trivandrum (8.68°N, 77.0°E, dip. 3°N) and Alibag (18.61°N, 72.83°E, dip. 24.8°N) as well as the ionospheric height parameters reduced from the ionograms of Trivandrum and Ahmedabad (23.0°N, 72.67°E). It has been found that the dayglow diurnal patterns are characteristically different (conical, relatively faster rise and fall) on the days when counter electrojet are present over equator. It has also been noticed that the diurnal patterns have characteristic features (flat topped, overall slower rate of variation) on normal electrojet days. This work has been carried out in collaboration with R. Sridharan and K.S.V. Subbarao of SPL, VSSC, Thiruvananthapuram.

(D. Chakrabarty, R. Sekar, H. Chandra, R. Narayanan)

On the Control of Ionospheric Parameters in 630.0 nm Thermospheric Dayglow Emission

The day-night photometer was operated from Waltair (17.7°N, 83.3°E, 10.09°N dip. lat.) during March, 1998, as a part of coordinated campaign under ISTEP program. These dayglow results together with the ionosonde data show the base height of the F layer (h'F) to be anti-correlated with the 630.0 nm dayglow intensity similar to the nighttime condition. A new empirical relation linking the F region electron densities and the h'F has been worked out highlighting the control of the ionospheric parameters on the chemical processes responsible for the 630.0 nm dayglow and its variabilities. This work was carried out in collaboration with Prof. R. Sridharan, SPL, VSSC, Trivandrum.

(Alok Taori, D. Chakrabarty, N.K. Modi and R. Narayanan)

Role of Fe^+ Ions in the Development of Equatorial Spread-F

Satellite and rocket measurements conducted over the years revealed the presence of Fe^+ in the F-region during equatorial spread-F (ESF) events. However, the role of Fe^+ in ESF is not yet completely understood. Recently conducted Leonid experiment also revealed the dominance of Fe^+ ion in the E-region and the presence of extended ESF during morning hours. In view of these observations and also to explore the possible effects of metallic ions, a linear theory of equatorial spread-F developed for two constituents was extended to multiple ions. The growth rate expression reveals that the metallic ions (Fe^+) can assist the growth of instability if and only if the gradient of the altitude distribution of metallic ion is positive in the F-region. Previous investigations by others indicate that such positive gradients depend on the production rate of metallic ions and also the time varying vertical plasma drift velocities.

(E.A. Kherani and R. Sekar)

An Interpretation of the Plume-like Structures in the Nighttime E-region at Low Latitudes

In order to understand the recent high resolution Indian MST radar observations of plume like structures in the plasma densities of the nighttime E-region at low latitude station by others, an investigation was made to explore the possibility of the interaction between the E and F region structures. The investigation revealed that the fringe fields associated with the development of equatorial spread F (ESF) structures initiated by large scale waves in the zonal direction can penetrate well below the E-region. These fringe fields pull the structures upward either from eastern or western side of the observation station and thus cause plume like structures in the E-region. The depth of penetration of the fringe fields from the F region altitudes mainly depend on the wavelength of initial perturbation. The fringe fields can move the E-region structures upward with varying speeds even when the background drift during nighttime is downward, depending on the strength of ESF development. This work is carried out in collaboration with Prof. R. Raghavarao.

(E. A. Kherani and R. Sekar)

Coordinated Radio and Optical Measurement during Equatorial Spread-F

A coordinated multi-instrumented campaign was conducted from low and equatorial regions during March 1998 and 1999 under the ISTEP programme. The RTI and RTV maps obtained from Indian MST radar were compared with the 630 nm emission intensities obtained over Waltair using day-night photometer in a bi-directional mode (zonal). Similar structural patterns were obtained on three common nights by both optical and VHF radar. The downward moving structure as observed by VHF radar was identified to be an enhancement in 630 nm emission intensities corresponding to enhancement in ambient ionization. The zonal drifts are estimated using the identifiable structures in emission intensities obtained from bi-directional scanning. This work is done in collaboration with Prof. P.B. Rao of NMRF, Tirupati.

(R.Sekar, E.A. Kherani, D. Chakrabarty and Alok Taori)

Rocket Experiments Conducted during Leonid Meteor Shower –1999

Electron density measurements were carried out from SHAR on 18 and 20 November, 1999 at 7.25 hrs and 7.03 hrs., respectively. This corresponds to solar zenith angle of 75° and 80° respectively. The electron density profiles were measured from 75 to 139 km and 75 to 136 km. The electron density profiles on both the days clearly show solar zenith angle dependence. There were no sharp layers in E region on both the days. The irregularities in scale size 1-100 meter were not seen in E region. The electron density shows positive gradient between75 to 100 km and negative gradient from 110 km till apogee. The absence of irregularities in both the positive and negative gradients shows that the ambient electric field might be weak at the time of flight. Moreover, there was a magnetic storm on 16 November and the rocket flights took place during recovery phase of the storm. MST radar at Gadanki was operational on both the days during rocket flight time. The MST radar did not report the presence of 3m size irregularities on either of the day. The groundbased and rocketborne measurements agree very well.

(S.P. Gupta, R. Sekar, Y.B. Acharya and S.R. Das)

Leonid Meteor Showers and the Ionospheric Effects over Ahmedabad

Ionosonde data over Ahmedabad were examined to study the effects of the Leonid meteor showers. Radio soundings were made every five minutes for the days 16-20 November of the years 1998-2000. Hourly data for the years 1994-2000 were also used in the study that shows an enhanced sporadic-E occurrence activity associated with the Leonid meteor showers starting from 1996 and peaking in 1998. Ionograms recorded during the nights of peak meteor shower activity during the year 1998, show increases in both the parameter f_oE_s and f_bE_s. Multiple traces between 100 and 150 km appear on some occasions for both the years 1998 and 1999, which lend support to the association of meteor shower with the sporadic-E observed. Thus there is clear evidence of the enhanced sporadic-E related to the Leonid shower.

(Som Sharma and H Chandra)

Radio Signatures of Leonid Meteor Shower on Transionospheric VHF Satellite Signal

VHF scintillations of the 244 MHz satellite beacon from the geo-stationary satellite FLEETSAT (73° E) recorded at Haringhata field station (23° N, 88.5° E) of the Calcutta University during the night of 16-17 November 1998 are shown to be associated with the sporadic-E layer generated by meteoric ionization. Two examples of scintillations corresponding to the peak period of Leonid meteor shower are transient and quasi-periodic in nature with much shorter duration (30-100S) than normally observed during the nighttime. Critical frequency of the sporadic-E layer (f_oE_s) obtained from the radio soundings over Ahmedabad (23° N, 72.4° E) for the same night also shows two isolated spikes. The occurrence of the oscillating diffraction patterns due to the meteoric ionization is validated from the model plots obtained using the diffraction theory from a series of one-dimensional irregularities. This work is carried in collaboration with Prof. A. Dasgupta of Calcutta University.

(H Chandra)

Planetary/Cometary Atmospheres

Electron Spectra in the Dayside Martian Ionosphere

A time series of electron and magnetic field measurements was made by Electron Reflectometer and Magnetometer experiments onboard Mars Global Surveyor on April, 2 1998. Photoelectron flux at solar zenith angle 70 degree for energy ranges 10-1000 eV using solar extreme ultraviolet radiation between 1 and 102.57 nm were calculated using analytical yield spectrum approach based on Monte Carlo method. Two dimensional yield spectra was used to calculate the photoelectron flux as a function of energy and altitude, where the magnetic field was horizontal in direction such as observed by MGS on April 2, 1998. The calculated photoelectron spectra are plotted at altitudes 125 km, 150 km, 225 km, 300 km and 350 km (**Fig. 5.5**). The electron flux was measured at 225 km by the electron reflectometer experiment in the ionosphere of Mars. These results are in good agreement with the observations and suggest that X-ray ionization is an important process in the upper ionosphere of Mars at energy greater than 90 eV and 10-90 eV.

(S.A. Haider)

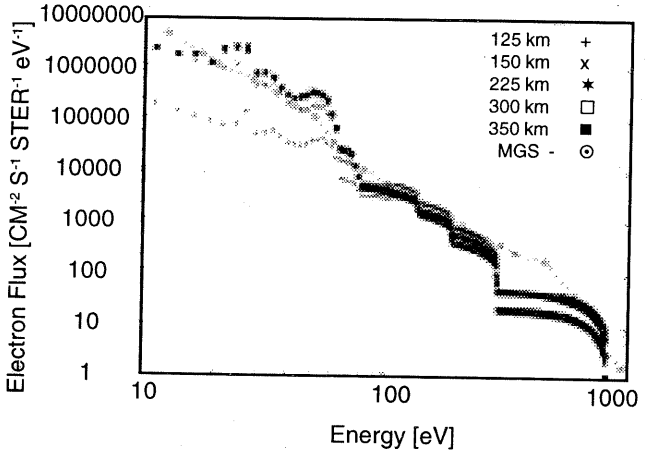


Fig.5.5 Electron fluxes at different altitudes. Electron Reflectometer measurements at 225km are shown by circles and dashed lines.

Dynamics of Martian Ionosphere

Mars Global Surveyor (MGS) observed for the first time the magnetic field and electron density at different places within the ionosphere between 100 km and 400 km. MGS discovered that solar wind dynamic pressure nearly permanently compresses the interplanetary magnetic field into Martian ionosphere up to 180 km. In presence of induced magnetic field the electron density was calculated using one dimensional continuity and momentum equations using the observed magnetic field of 50 nT. It was found that this magnetic field was enough to reproduce the measured electron density as observed by MGS above 200 km. Below this altitude the ionosphere of Mars is not affected by induced magnetic field. This suggests that the dynamics of the Martian ionosphere is controlled by a strong convection which is likely to be driven by the pressure gradient force or the electromagnetic force driven by the solar wind.

(S.A. Haider)

Laboratory Astrophysics

Spectroscopy of Laser Produced Plasma

An experiment to study the emission spectrum of laser produced plasma (LPP) from metals has been started. Proper collection optics has been developed to spatially resolve the emission along the direction of evolution of LPP with an accuracy of fraction of a millimeter. The composition of the plasma is characterized at different regions by studying their emission features. The plasma is produced by the interaction of high density (>5 MW/cm^2) laser beam (308 nm XeCl excimer laser) on aluminum metal placed in vacuum. The spectra are recorded using a CCD spectrograph. Various emission lines from neutral and ionic states are identified along with continuum due to electron recombination processes. Effects of additive gases in quenching the line emissions and re-modifying the continuum are also being studied in detail.

(K.P. Subramanian, I.A. Prajapati, V. Kumar and A.P. Gohil)

Development of Software for Interfacing Digital Storage Oscilloscope

A software for setting parameters and acquire waveform (SPAW) from Tektronix TDS 540 digital storage oscilloscope (DSO) has been developed. This software was written in C language. The software conforms to the general purpose interface bus (GPIB) protocol (IEEE 488.2 standard) and the instruments are interfaced through a GPIB card in the master controller PC. The software could be used to set many parameters (that are most commonly used) in the DSO, run an acquisition sequence and transfer the data to PC for off-line analysis. The SPAW software was further extended to develop an additional mode of acquisition, viz. ADD mode, otherwise not available in the DSO. Synchronization of the repetitive signals with respect to internal or auxiliary (external) trigger, swapping of single sequence waveform to PC buffer and frame additions was accomplished to develop the ADD mode.

(K.P. Subramanian and A.P. Gohil)

Remote Controlling of Laboratory Equipment using LabVIEW Software

Laboratory instruments that conform to IEEE standard are interfaced using the GPIB card in a PC in which *LabVIEW* software has been installed. Virtual interfaces (VIs) are developed for the interfaced instruments by virtue of which instruments can be accessed and controlled by the remote PC master controller. The VIs are developed in graphical language G. Scope of *LabVIEW* include on-line visualization of data, sequencing of controls and controlling flow of data across modules. The Tektronix DSO TDS 540 has been interfaced with PC using *LabVIEW* software. Work is in progress to interface other instruments in the laboratory.

(K.P. Subramanian and A.P. Gohil)

The programmes of the Division are being carried out by two separate scientific areas: (i) Oceanography and Climate Studies and (ii) Solar System and Geochronology. The research activities of the Oceanography and Climate Studies area focus on the following themes: (i) studies of past climate and environment, especially those pertaining to the Indian region through analyses of their records in a variety of continental and marine archives, (ii) ocean circulation and ocean-atmosphere interactions, (iii) weathering and transport of elements from land to ocean based on the chemical and isotopic composition of rivers draining the Himalaya and the Deccan Traps and (iv) surface Hydrology with emphasis on moisture budget of monsoon and contaminant transport through ground waters. The programmes of the Solar System and Geochronology area include studies of (i) formation of the Sun and the Solar System objects, such as planets, satellites and asteroids and the processes governing their evolution, (ii) chronological evolution of prominent geological features on the Indian shield such as the Himalayas, the Deccan Traps and the Early Archean blocks and (iii) geochemical studies of catastrophic (boundary) events in Earth's geological history and their plausible causes.

Oceanography and Climate Studies

Thermoluminescence Studies of Deserts

Thar Desert : The southern margin of the Thar Desert extending upto Gujarat contains record of the past dune activity. Chronometric studies using Blue Green Light Stimulated Luminescence (BGSL) on quartz extracts of six fossil dunes excavated in the Sabarmati and Mahi basins have revealed that dune accretion in this area commenced with the gradual decline of a humid phase that terminated at 30 ka. During this humid phase (50-30 ka), the region experienced a large-scale fluvial aggradation. Evidence of dune accretion during the Last Glacial Maximum (LGM) at 20 ka is at variance with the core Thar Desert where dune accretion postdates the LGM. Enhanced sand supply from extensive alluvial plains and exposed continental shelf of the Arabian Sea perhaps facilitated such a dune accretion. Fluvially reworked aeolian sand and microlithic artifacts in the stabilized dunes (dated to 11- 8 ka) indicate a period of quiescence in dune accretion.

Deserts of United Arab Emirates and Oman : Geomorphological studies and luminescence dating of various landforms from Arabia have led to the following inferences: (1) During the last 300 ka the region experienced repeated dune-sand reworking/ transport/deposition by the opposing NW Shamal and SW Monsoon winds; (2) Major dunes (like the E and SE-extending linear dunes) formed around the LGM when the clockwise rotation of the Shamal wind system was active. However, its axis of rotation was displaced southward facilitating transportation of sand across the coast to the exposed narrow continental shelf of the Arabian Sea; (3) During deglaciation (between 12 to 6 ka) the Shamal wind system weakened and the sea transgressed northwestward by over 1000 km across the exposed Arabian Gulf. This resulted in withdrawal of aeolian input to Emirate coast from the exposed gulf; (4) In Oman, a weakend Shamal enabled northward progression of the more humid SW Monsoon system depositing quartz and carbonate grains from the continental shelf of the Arabian sea in Wahiba area. IRSL ages of SW-NE aligned dunes and aeolinites are dated at 112 and 229 ka suggesting their deposition during the strengthening of SW monsoon similar to that of the Thar Desert.

Chronology of Ganga Basin

The sedimentary sequences from the Gangetic foreland basin provide a record of the past 100 ka and indicate that the upland fluvial surface began accreting prior to 80 ka and the region experienced a humid phase during 70-30 ka. The mega-fan surface formed prior to 8 ka. The river valley terrace formed during 7 to 1.5 ka and the present active terrace began accreting since 1.5 ka. Luminescence dating of alluvial ridges overlying fluvial sands indicates a climatic shift during 7-5 ka when the fluvial activity gave way to aeolian aggradation. Distribution pattern of ponds in the region suggests their formation due to cessation of fluvial activity in upland interfluves and changes in the hydrologic budget. The sedimentation pattern in the southern part reflects a control of foreland bulge created by the subduction of the Indian plate.

History of Sabarmati River

Earlier studies suggested that the present N-S flow of river Sabarmati is not consistent with the regional NE-SW slope and there must have been a change in the direction of flow in the past. A study was undertaken to date the river capture event and understand the processes that led to such a slope adjustment and subsequent incision by the river. Luminescence chronology (BGSL and IRSL) of the fluvial and aeolian sequences around Mahudi shows that Sabarmati River adjusted to its present course as a result of tectonism in the region. The river adjustment and subsequent incision occurred during 12 to 4.5 ka governed by increased fluvial activity. The basin experienced two major tectonic events at 3000 a and 300 a that caused the river to further incise by ~2 m each time.

Collaboration with M.D. Bateman, L.S. Chamyal, K.W. Glennie, A. Kar, G. Kocurek, N. Lancaster, S.N. Rajaguru, I.B. Singh, D.S.G. Thomas, J.T. Teller, R. Vernet, R.J. Wasson, Z.S. An and Z.P. Lai is acknowledged.

(M. Jaiswal, N. Juyal., V. Pande, A.K.. Singhvi and P. Srivastava)

Palaeomonsoon/Palaeoproductivity Studies using Eastern Arabian Sea Sediments

Palaeoproductivity variations in the southeastern Arabian Sea, during the late Quaternary period (~ 45 ka B.P. to present), have been studied using accumulation rates of sedimentary biogenic components like organic carbon (C_{org}), nitrogen (N), $CaCO_3$ along with Sr and Ba. The results show decreased surface productivity during the last glacial inteterglacial transition. The observed oscillations of surface water productivity during the last glacial-interglacial period are in contrast to those observed in other low and mid-latitude upwelling areas, but consistent with those in the upwelling regions of NW Africa and NW Mexico. The provenance effect and intensity of aeolian transport did not change significantly in the SE Arabian Sea as revealed by constancy of Ti/Al ratios.

A high resolution record of Holocene climate using a sediment core (3268G5) from the eastern Arabian

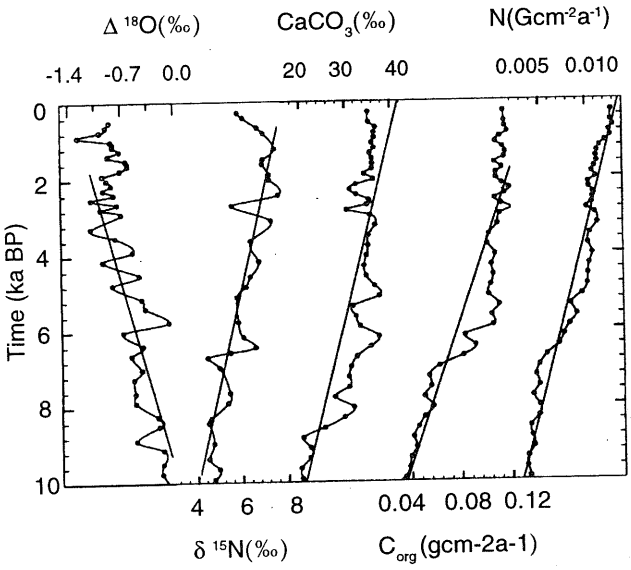


Fig. 6.1 Past variations in palaeoclimatic proxies of eastern Arabian sea core 3268G5. Increasing monsoon intensity (decreasing $\Delta^{18}O$) accompanied by increasing trends of biological productivity ($CaCO_3$ and C_{org} variations) and associated subsurface denitrification increase ($\delta^{15}N$) are clearly seen between ~10kyr and 2 kyr before present.

Sea reveals increase in surface productivity from 10 ka to present accompanied by increasing trend in sub-surface denitrification and monsoon intensity (**Fig. 6.1**). Two dominant periodicities (~ 1400 and ~ 700 years) are observed in geochemical and isotopic proxies which were earlier noticed in south Asian monsoon as well as at high latitude ice core and Canadian lake records.

High resolution measurements of organic carbon and nitrogen, Al, Fe and Mg on a core from the NE Arabian Sea for the past millennium are compared with available data on Total Solar Irradiance (TSI) deduced from ^{10}Be measurements on ice cores. The results, based on both pattern matching and spectral analysis, show the influence of solar activity on the monsoon rainfall and its manifestations in the form of surface productivity in the eastern Arabian Sea and river discharges. The AMS radiocarbon ages on planktonic foraminifera are provided by Drs. A.J.T. Jull and G.S. Burr NSFAMS laboratory, Arizona, USA.

(R. Agnihotri, S.K. Bhattacharya, R. Ramesh, A. Sarkar, M.M. Sarin and B.L.K. Somayajulu)

Seasonal Variation of Water $\delta^{18}O$ at the Ganga Estuary

Ganga-Sagar estuary is one of the largest of its kind in the world, covering an area of 4200 sq km and discharging an enormous volume of fresh water derived from monsoon rainfall and melting of Himalayan glaciers. In order to understand the variation of these two water fluxes through the year we have sampled water from Kakdwip (Ganga-Sagar) which experiences strong neap and spring tides. Oxygen isotopic composition of the samples were determined using on line water equilibration system attached with GEO 20-20 mass spectrometer. The results show that during October to January $\delta^{18}O$ is low and varies between -6 to -9‰ while from February the water starts getting enriched (-5 to -6‰ till May). During July to September the value is highest and remains almost constant at -4 ± 1‰. The depletion during October to January is probably due to large contribution of water from melting of glacier. This period is followed by evaporative enrichment of melt water between February to early May. Subsequently, monsoon rain contributes dominantly between July to September. Analyses of δD and $\delta^{13}C$ of bicarbonates are in progress. This work is in collaboration with Prof. A. Chakrabarti of IIT, Kharagpur.

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

Satellite Oceanography and Carbon Cycle

Two new programs have been initiated this year relating to satellite oceanography. In the first, satellite data is used to derive the geoid fields and discern the regional tectonism, particularly in the Bay of Bengal region. Fourier analysis of the anomaly fields in the geoidal variations gives information about the subsurface geodynamics (e.g. ocean floor spreading from the mid-ocean ridges, orientation and distribution of fracture zones, seamounts and their role in regional tectonism). To this end, the instantaneous sea surface height (SSH) obtained from ERS-I (168 days) and Geosat (geodetic phase) have been processed to remove seasonal variations in the ocean surface by winds and tides. Further processing removes bathymetric variations and deeper earth effects. The residual geoidal undulations split over different spatial wavelengths have been calculated and are stored in image form. A major NE-SW trending fracture zone at the southern Bay of Bengal lithosphere has been found. The second project pertains to global carbon cycling. The Arabian Sea is known to support high primary production during the monsoon season. To calculate the primary production, we require two parameters, the light attenuation coefficient K and the Chlorophyll content of the mixed layer. Using Ocean Colour Monitor data from IRS satellite, these were calculated for different seasons over the north-eastern Arabian Sea. It is seen that in the Gujarat Coast even during the winter, the productivity exceeds 2 $gC/m^2/day$. There is also a sharp gradient of productivity, which drops to 200 $mgC/m^2/day$ within 100 km from the coast. Long term seasonal monitoring will provide data of carbon fluxes from the atmosphere to the ocean in this region. This work was carried out in collaboration with scientists from the Space Applications Centre, Ahmedabad.

(S. Kumar, S. Rajesh and R. Ramesh)

^{14}C of Atmospheric CO_2 over the Northern Indian Ocean

Considerable variations of ^{14}C over the Arabian Sea and the Bay of Bengal region have been observed during the spring of 1993 to 1995 and 1997 to 1999 reflecting both regional and inter-annual variations. The inter-annual variations of ^{14}C of the tropospheric CO_2 over this region is found to correlate with the El Nino/ Southern Oscillation (ENSO) events, with positive excursions of $\delta^{14}C$ before the onset of warm phase of ENSO. $\delta^{14}C$ is found to be decreasing at the rate of 5‰ yr^{-1} and the decrease corresponds to average e-folding time of about 17 years for the removal of tropospheric ^{14}C over this region. The rate of this decrease is not uniform. It is about 7‰ higher than the expected trend, during the very strong El Nino event of 1997-1998. $\delta^{14}C$ in air overlying the Arabian Sea appears to be lower than that over the Bay of Bengal (by about 5‰). This is due to the fact that the Arabian Sea is a perennial source of CO_2, from the upwelling of ^{14}C depleted CO_2 rich water.

(R. Bhusan, K. Dutta and B.L.K. Somayajulu)

Sr Isotopes in the Yamuna River System in the Himalaya

Sr abundances and Sr isotopes along the Yamuna River System in the Himalaya have been determined to assess carbonate and silicate weathering in this region and associated CO_2 consumption rates. The abundances are low during the monsoon and high during pre-monsoon. The TDS in the Yamuna main stream and its various tributaries range between 30 to 2400 mg/l, Sr abundance between 120 to 62000 nM/l and $^{87}Sr/^{86}Sr$ between 0.7142 to 0.7932. The concentrations of Sr and $^{87}Sr/^{86}Sr$ of the Yamuna waters (excluding a few spring samples with very high Sr in the lower reaches of the Yamuna) fall in the same range as those in the Ganga headwaters. The $^{87}Sr/^{86}Sr$ is anti-correlated with Sr indicating two component mixing. The composition of the dissolved loads in the rivers and those of the major lithologies they drain, i.e. crystallines and Precambrian carbonates, allows us to constrain source(s) of major ions and Sr to these rivers. Using Na as an index of silicate component, it is estimated that on an average, ~ 25% of Sr in these waters is of silicate origin. Further, a positive correlation between $^{87}Sr/^{86}Sr$ and silicate Sr in the waters indicates that silicate weathering is an important source of the high radiogenic Sr to the waters. Analogous to the Ganga headwaters, the Sr/Ca in the Yamuna waters is generally higher than those in Precambrian carbonates, ruling them out as a major contributor to the Sr budget of these rivers. The positive correlation between SO_4 and Sr and inverse correlation between SO_4 and $^{87}Sr/^{86}Sr$ (**Fig. 6.2**) show that dissolution of gypsum and/or phosphorites can also be significant sources of Sr to these waters. Thus, it appears that the two end members regulating the Sr isotopic composition of the Yamuna River System are the high $^{87}Sr/^{86}Sr$ and low Sr silicate component and the low $^{87}Sr/^{86}Sr$ and high Sr (carbonate, sulphate, phosphorite) component. The negative correlation between $^{87}Sr/^{86}Sr$ and TDS, Ca + Mg and SO_4 attests to the idea that weathering of carbonate, evaporite and phosphorite serves to reduce the high (radiogenic) Sr isotopic ratio of the waters. This work is done in collaboration with Dr. Anil Kumar of National Geophysical Research Institute, Hyderabad.

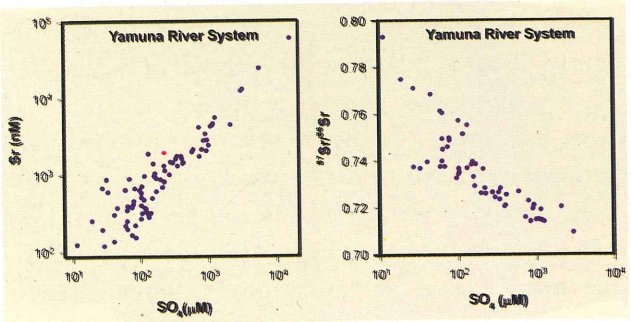


Fig. 6.2 Co-variation of Sr and $^{87}Sr/^{86}Sr$ with SO_4 in the Yamuna River System in the Himalaya

(Tarun K. Dalai, S. Krishnaswami and J.R. Trivedi).

Chemical and Isotopic Characterization of Atmospheric Aerosols

Chemical characterization of atmospheric aerosols over the urban atmosphere, high altitude regions and in the marine boundary layer (MBL) can help in understanding the relationships among sea-salts, mineral aerosols, biogenic emissions and several anthropogenic substances (SO_4^{2-}, NO_3^-, NH_4^+ and heavy metals). The concentrations of environmental radionuclides, ^7Be and ^{210}Pb, and their characteristic variations help to understand the temporal variation in the vertical atmsopheric mixing, aerosol scavenging and deposition processes. Preliminary results indicate that during the winter months, ^7Be concentration over Ahmedabad ranges from 2.8 to 5.6 mBq/m^3 whereas during monsoon period it is relatively low (0.8 – 2.5 mBq/m^3). In contrast, ^{210}Pb concentration does not show significant seasonal variation; its concentration ranges from 0.2 to 0.5 mBq/m^3. The water soluble components, Cl^-, SO_4^{2-} and Na^+, in the aerosols show an increasing trend during June-August period suggesting their derivation from the marine salts. The areal distribution of ^{210}Pb concentrations over the Arabian Sea and the Bay of Bengal shows large variations (from 0.27 ± 0.04 to 1.7 ± 0.2 mBq/m^3) and there is no pronounced seasonal pattern. However, on an average, aerosol ^{210}Pb concentrations in the MBL over the Bay of Bengal were 25% higher than those observed in the Arabian Sea. In contrast, aerosol ^7Be concentrations were distinctly higher (range:

2.77 ± 0.07 to 13.20 ± 0.23 mBq/m^3) in the Arabian Sea during the period of late NE monsoon (February) than those over the Bay of Bengal (0.61 ± 0.02 to 2.94 ± 0.02 mBq/m^3). The average deposition flux of ^{210}Pb over the Arabian Sea and Bay of Bengal is about 270 Bq/m^2/yr and that of ^7Be is about 1100 Bq/m^2/yr. However, the ^7Be dry-deposition flux over the Arabian Sea is nearly 50% higher than that over the Bay of Bengal. The episodic high inputs of ^7Be in the tropical Arabian Sea could be associated with the dust storm activities indicating transport of pollutants from the Indian subcontinent during winter months.

(Neeraj Rastogi, R. Rengarajan and M.M. Sarin).

Chemical Constituents in Rainwater over Urban Atmosphere

The purpose of this study is to investigate the variations of chemical constituents in rainwater in terms of natural and anthropogenic sources. In this context, twenty individual precipitation events were sampled during the period 2 July – 5 September. 2000 from the terrace of the eight-storey PRL main building in Ahmedabad. The total rainfall during individual events ranged from 2 mm to 40 cm. Concentrations of major cations and anions (NH_4^+, Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^-, SO_4^{2-} and HCO_3^-) were measured along with pH and EC. To check on the quality of the chemical analysis, anion and cation balances were calculated for each precipitation event. The mean cation to anion ratio was 0.97 with a range of 0.90 to 1.05. The pH of rainwaters ranged between 6.09 to 7.35 units and the TDS concentration varied from 3.2 to 45 mg/l with systematically higher concentration of salts during low rainfall events.

In each rain event, Ca^{2+} dominated the cations whereas HCO_3^- and SO_4^{2-} together made up for the bulk of the anions. However, it is noteworthy that contribution of Na^+ and Cl^- was significant in the rain events occurring after prolonged dry period. Abundance of Na^+ (range: 7.0 to 137 meq/l) has been used as a reference for sea-salts. The percent non-sea-salt fraction for K^+, Mg^{2+}, Ca^{2+}, Cl^- and SO_4^{2-} varied widely among precipitation events (K^+: 47-96%, Mg^{2+}: 22-68%, Ca^{2+}: 96-99%, Cl^-: 2-50% and SO_4^{2-}: 79-98%) suggesting that the concentration of these constituents is dominated by anthropogenic and dust related sources with only minor influence of sea-salts. Among other anthropogenic constituents, NO_3^- and NH_4^+ concentrations in the rain events ranged from 0.5 to 61.3 meq/ l and 0.5 to 220 meq/l respectively.

(Neeraj Rastogi and M.M. Sarin).

Geochemical and Isotopic Studies of Mine Waters

The physical and chemical weathering processes in coal, pyrite or sulfide mines occur in a special way. The oxidation of the various sulfide minerals produces sulfuric acid which dissolves in waters and causes chemical reactions with the wall rocks.Therefore, the concentration levels of various dissolved species will vary as a function of pH of the water. Several water samples were collected from coal mines in two areas: Chandrapur district in Maharashtra and Dhanbad district in Jharkhand. The initial characterization of these waters has been done through the pH measurements and major ion chemistry. Results show that concentrations of cations and anions vary from 4500 to 20000 mmol/l. SO_4^{2-} and HCO_3^- constitute ~75% of the anions on an equivalent basis while (Ca + Mg) are the major cations. The total dissolved solid (TDS) varies from 400 to 1300 mg/l. The anions constitute 70-80% of the TDS and HCO_3^- is the major anion. To decipher the source of dissolved inorganic carbon, $\delta^{13}C$ of HCO_3^- in water is being measured. Initial results yield values in the range of -2.6 to -26.6‰; it is interesting to note that the most depleted value might be an indicator of CO_2 produced from methane oxidation as methane is often abundant in parts of these mines.

(S.K. Bhattacharya, Anirban Das, S. Krishnaswami and M.M. Sarin)

Non-mass Dependent Oxygen Isotopic Fractionation in Ozone.

It has been known for sometime that the oxygen isotopic composition of stratospheric ozone is characterised by large and nearly equal enrichment in heavy isotopes ^{18}O and ^{17}O compared to the ambient oxygen from which ozone is formed and contrary to the normal isotopic pattern where $\delta^{17}O$ is about half of $\delta^{18}O$.

Several models to explain the Mass Independent Fractionation (MIF) have been proposed but none of them can satisfactorily explain all the experimental results obtained so far. To put constraints on the models, we have carried out isotopic analysis of ozone formed by UV photolysis of oxygen by varying the ambient pressure and time of exposure. Ozone was formed in a 5 l spherical flask containing oxygen at pressures varying from a few torr to a few hundred torr and irradiating the oxygen by UV light obtained by using microwave excited UV lamps (Hg and Kr gas containing lamps providing UV at wave lengths 185, 254, 124 and 160 nm). The formed ozone was separated and measured in GEO 20-20 IRMS for oxygen isotopic ratios. Large mass-independent enrichments in ^{18}O and ^{17}O were obtained whose magnitude varied with pressure (**Fig. 6.3**). More experiments are in progress to verify the amount dependence. The enrichment is approximately constant at higher pressure side while at pressures lower than 50 torr enrichment increases till attaining a peak at about 15 torr after which it starts to decrease. The data also show dependence of enrichment on the amount of ozone formed; the lower the amount the higher is the enrichment.

(S.K. Bhattacharya and Subrata Chakraborty)

Geochemistry of Late Neoproterozoic Carbonate Rocks of Rajasthan

The Bilara Group of the Nagaur-Ganganagar basin in western Rajasthan comprising of limestone and dolomite has been investigated to decipher its chemostratigraphic correlation with globally recorded Neoproterozoic-early Cambrian successions. Based on 200 thin sections and 130 samples analyzed for carbon and oxygen isotopic ratios we have identified four prominent negative and three positive excursions in the depth profile of the carbon isotope ratio. Such repeated carbon isotopic perturbations are characteristics of terminal Proterozoic era caused by climatic fluctuations and instability in the marine carbon cycle. Preliminary organic carbon isotope data shows covariance with carbonate carbon isotope profile suggesting a primary carbon isotopic perturbation in the contemporary marine realm.

(S.K. Bhattacharya and A. Mazumdar)

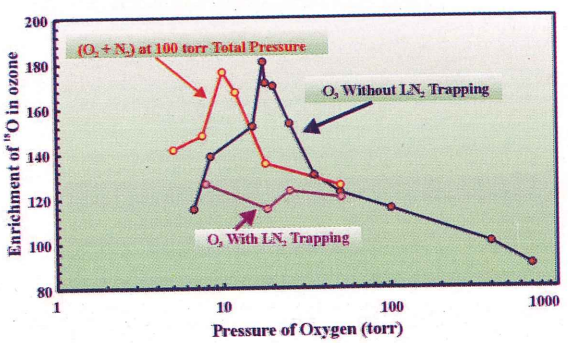


Fig. 6.3 Isotopic enrichment in Ozone formed by photolysis of Oxygen using Hg and Kr UV lamps.

Effect of Dual Monsoon System on Shallow Groundwater from Southern India

Surface and groundwater samples were collected from the southern Indian peninsula and analysed for oxygen and hydrogen isotopes. The objective was to isotopically characterise and understand the factors responsible for the observed geographical distribution in isotopes. The study was based on the assumption that the shallow groundwater retains the isotopic signature of the local precipitation averaged over a few tens of years. Locations of hand pumps and/or dug wells sampled and the contours of $\delta^{18}O$ values are shown in **Fig. 6.4.** It is seen that overall, $\delta^{18}O$ values vary within a range of ~ -2 to -5 ‰. The range is narrow, ~ -2 to -3 ‰ along the west coast, on the Deccan plateau and on Tamilnadu uplands and ~ -4 to -5 ‰ along the East Coastal Plains and Eastern Ghats. In addition to the effects due to altitude and latitude and evapo-transpiration, isotopic character of groundwater from south Indian peninsula exhibits a strong influence of the major regional geographical features and different sources of moisture during summer and winter rains. A significant recycling of the moisture is also indicated particularly in the area predominantly influenced by the summer SW monsoon.

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

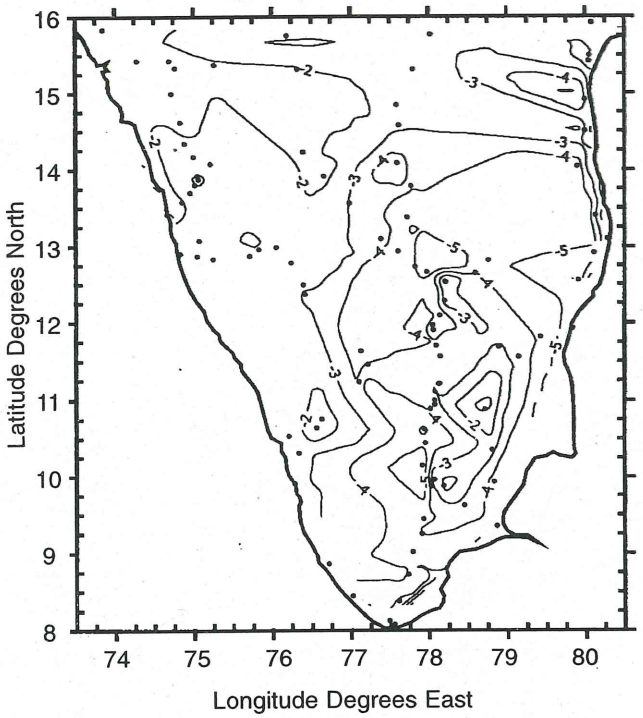


Fig. 6.4 Oxygen Isotope contours in ground waters of South India showing effect of SW monsoon in West coast and NE Monsoon in east coast.

Seismicity and Groundwater Helium in Bhavnagar, Gujarat

Bhavnagar city is known to have experienced intermittent seismicity of magnitude >3 during the past two decades. Following repeated tremors since August 2000, a survey of dissolved helium in groundwater was conducted in September 2000 in Bhavnagar. Twelve samples out of sixteen showed dissolved helium concentrations in excess of atmospheric equilibration value. Sampling was repeated in January 2001 and March 2001 to study the temporal variations of groundwater helium. A variation of > ± 100% is observed in some of the samples, particularly those that exhibit high levels of excess dissolved helium (inter-sample variability is < 5%). It is also noted that high groundwater helium is found largely in the basaltic aquifer. It is not yet clear if the observed high level of dissolved helium in shallow groundwater can be ascribed to the recent seismic activity or it could as well be an indication of high background resulting from local geological factors such as presence of faults, concentration of radioactive minerals or high residence time of local groundwater.

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

Controlling Factors in Evaporation from Surface Reservoirs

A significant part of the stored water in surface reservoirs in arid zones is lost by evaporation. Estimation of this loss can be made using mass balance equations for two different tracers. With this aim, six reservoirs in Gujarat (Dharoi, Dantiwada, Kadana, Shetrunji, Ukai and Bhadar) were selected based on their varied geographical locations, geological setting and climatic conditions. Analyses of EC (Electrical Conductivity), TDS (Total Dissolved Solids), Na^{+1}, and Cl^{-1} have been completed. The Dantiwada reservoir on Banas River showed maximum temporal fluctuations in the TDS and ionic concentrations even though there was a steady decline in reservoir volume towards the later stages of annual cycle. The Cl: Na ratio was 0.75 ± 0.07. Dharoi reservoir on Sabarmati River showed a steady declining trend in volume with some fluctuations in ionic concentrations. The average Cl: Na ratio was 0.92 ± 0.03, the highest value obtained among the four. Kadana reservoir on Mahi River showed a rapid decrease in volume soon after the monsoon period indicating release/ utilisation of water followed by a small increase in volume in winter. This increase was caused by groundwater inflow from the catchment area. The average Cl: Na ratio turned out to be 0.41 ± 0.03 the lowest among the four reservoirs. A steady evaporative trend both in volume and ionic concentrations was observed for Shetrunji reservoir. The average Cl: Na ratio was 0.57 ± 0.02. It was seen that Cl: Na ratio had a characteristic value for each reservoir and did not show much fluctuation

(R.D. Deshpande, S.K. Gupta, Sajan Nair and V. Somayajulu)

Solar System and Geochronology

Correlated Studies of Extinct Nuclide Records in Early Solar System Objects

The *in situ* decay of short-lived radionuclides such as ^{26}Al and ^{41}Ca in refractory Ca-Al-inclusions (CAIs) of primitive chondrites offers the possibility to develop a detailed chronology of high temperature, early solar system processes. A correlation of ^{26}Al and ^{41}Ca in some CAIs obtained by us earlier provides evidence for ex-

ternal seeding of these nuclides by freshly produced radioactive stellar materials. However, the recent discovery of ^{10}Be ($t_{½}$ = 1.5 Ma) in an Allende CAI points to an irradiation source for at least some short-lived radioactivities. We have initiated a quantitative investigation of correlation of ^{10}Be with ^{26}Al and obtained new Be-B data on a CAI (E44) from the Efremovka meteorite that we have studied earlier and obtained evidence for the presence of ^{26}Al and ^{41}Ca. Our data show presence of ^{10}Be at the time of formation of E44. These results suggest that there could be widespread occurrence of live ^{10}Be in the early solar system. However, unlike the case for ^{26}Al and ^{41}Ca, there is a spread in the initial ^{10}Be abundances in the CAIs. If this indeed represents a difference in time of formation, ^{26}Al and ^{41}Ca studies of these samples will be crucial to understand the source and inventory of the short-lived nuclides in the early solar system. This work was carried out in collaboration with scientists at the University of California, Los Angeles and University of Hawaii, U.S.A.

(J. N. Goswami)

Oxygen Isotopic Records in Hibonites from CM Meteorites

Thermodynamical, chemical and mineralogical considerations suggest the refractory oxide-rich inclusions in CM meteorites to be some of the earliest solids to form in the solar nebula. Refractory hibonites [Ca, Al (Mg, Ti) Oxide] in the CM chondrite Murchison display large magnitude stable isotopic abundance anomalies in ^{16}O, ^{48}Ca and $^{49,50}Ti$ and also have radiogenic isotopic anomalies due to decay of short-lived nuclides ^{41}Ca and ^{26}Al. We have investigated additional hibonites from Murchison as well as another CM meteorite, Murray, to further investigate these trends with special emphasis on oxygen isotopic records. All the analyzed hibonites show anomalous ^{16}O-rich isotopic composition. On a three isotope plot (**Fig. 6.5**) our data lie on the ^{16}O-mixing line (CCAM) defined by oxygen isotopic data for a large number of meteoritic CAIs. No obvious correlation of the data with morphology of the hibonites or with radiogenic ^{26}Mg or Ti isotopic anomaly in them could be found. The data appear to suggest that the

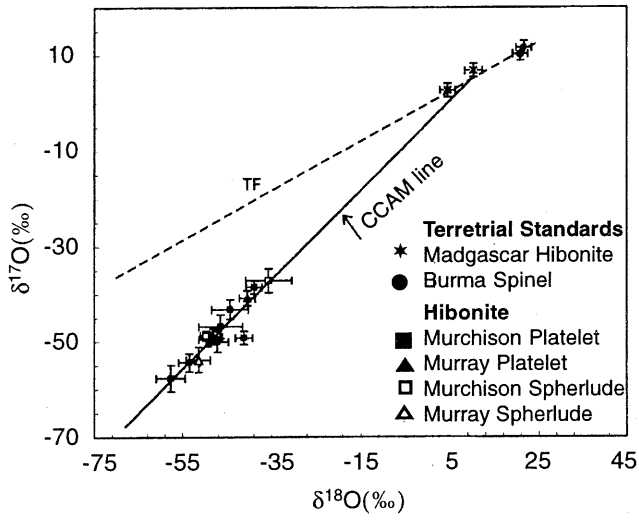


Fig. 6.5 Oxygen isotopic data for hibonites from two CM chondrites, Murchison and Murray. $\delta^{17}O$ and $\delta^{18}O$ represent deviations in the measured $^{17}O/^{16}O$ and $^{18}O/^{16}O$ ratios from the reference value ($\delta^{17,18}O$=0). The CCAM (carbonaceous chondrite anhydrous mineral) line represents the trend seen in oxygen isotopic data for a large number of refractory early solar system objects. Data for terrestrial standards plot along the terrestrial fractionation (TF) line.

hibonite sampled a reservoir enriched in ^{16}O that did not get depleted significantly over the entire duration of hibonite formation, while the reservoir of the exotic ^{48}Ca and ^{50}Ti got depleted either by removal and/or mixing. This work was carried out in collaboration with scientists at the University of California, Los Angeles, U.S.A.

(K. K. Marhas, N. Sinha and J.N. Goswami)

Time Scales of Formation of Eucrites

Eucrites are some of the oldest products of basaltic activity in the solar system with crystallization ages close to 4.55 billion years. The now-extinct short-lived nuclide ^{26}Al is a plausible heat source for early melting and differentiation in the eucrite parent bodies. We have looked for the presence of the now-extinct nuclide ^{182}Hf ($t_{1/2}$ ~ 9 million years) in a couple of zircons from the eucrite Elephant Moraine 90020 using ion microprobe technique to understand the time scale of early magmatic activity in planetesimals. The ages of these zir-

cons were also determined by $^{207}Pb/^{206}Pb$ dating approach and are 4547±56 Ma and 4505±42 Ma, respectively. Hf-W isotopic studies of the zircons did not reveal resolved excess in ^{182}W (decay product of ^{182}Hf) and we infer an upper limit of initial $^{182}Hf/^{180}Hf$ of ~10^{-5}. This is much smaller than the value of $2x10^{-4}$ reported from studies of bulk samples of different types of meteorites, including eucrites, by using ICP-MS and TIMS techniques. However, our upper limit estimate is consistent with recent ion probe data on zircons of a couple of other eucrites and chondritic meteorites. The reason for the lower initial $^{182}Hf/^{180}Hf$ in the zircons is not clear at present, particularly for the older zircon, that formed within 20 Ma of the beginning of the solar system. This work was carried out in collaboration with scientists from National Institute of Polar Research, Japan.

(G. Srinivasan, K. K. Marhas and J. N. Goswami)

Boron in Chondrules

Meteoritic chondrules formed very early in the history of the solar system via quick crystallization of molten silicate droplets in transient high temperature events. Isotopic composition and abundance of boron were measured in fifteen chondrules from seven chondrites by an ion microprobe. Boron abundances are generally low and range between 80 and 500 ppb. No significant variation in the $^{11}B/^{10}B$ ratio is observed among these chondrules. Isotopic heterogeneities within individual chondrules are constrained to be < ±20‰ at >95% confidence level at a spatial scale of 20-30μm. This is significantly lower than the value of ±40‰ previously reported for chondrules from carbonaceous and ordinary chondrites. Our results show that potential B-isotopic heterogeneities in the solar nebula due to the presence of components with different B-isotopic signatures, such as boron produced by high-energy galactic cosmic rays ($^{11}Be/^{10}B$ = 2.5), or by the hypothetical low energy particle irradiation ($^{11}B/^{10}Be$ = 3.5-11) did not survive the chondrule formation processes to a measurable extent. This casts doubt on the claim by a French Group for the presence of an isotopically anomalous boron component in chondrules produced by low energy particle irradiation of the proto-solar cloud. This work was carried out in collaboration with scientists from the Max-Planck Institute für Chemie, Mainz, Germany.

(J.N. Goswami)

Origin of Chondrules and CAIs

Chondrules and CAIs are common constituents of most primitive chondrites and are formed during high temperature events in the solar nebula. To understand their origin and possible genetic relationship between them, we have initiated a systematic study of Al-Mg isotopic systematics in Al-rich-chondrules (ARCs) and CAIs from several groups of unmetamorphosed carbonaceous chondrites. The samples analyzed so far include a CAI(E65) and several ARCs from the reduced CV chondrite Efremovka and a hibonite bearing CAI from the R-chondrite Hughes. The primary refractory minerals in E65 have initial $^{26}Al/^{27}Al$ close to the canonical value of $5x10^{-5}$, while secondary mineral (nepheline) present in it is devoid of ^{26}Al. Only one of the three ARCs has resolved ^{26}Mg excess from ^{26}Al decay but with a lower initial value than the CAIs. The hibonite in the CAI from Hughes has well resolved radiogenic ^{26}Mg and a low initial $^{26}Al/^{27}Al$ of $(1.2±0.3)\ x10^{-6}$. If we assume a homogeneous distribution of ^{26}Al in the nebula in the CAI and chondrule forming regions, these data suggest that chondrule formation started after CAI formation and continued for a few million years. The absence of radiogenic ^{26}Mg in nephelene in E65 suggest that the secondary alteration took place after ^{26}Al had decayed below detectable limits. The data for CAIs from Efremovka and Hughes would imply an extended time duration of ~3 Ma for CAI formation. However, formation of a high temperature phase like hibonite appears unlikely at such a late stage and the lower value may suggest resetting of Al-Mg systematics by a secondary alteration event taking place when ^{26}Al was still extant. This work was carried out in collaboration with scientists from University of Munster, Germany and University of Hawaii, USA.

(G. Srinivasan)

Noble Gases in Individual Chondrules by Laser Probe Mass-Spectrometry

The newly commissioned Nd-YAG laser has been used to extract gases by incremental heating of individual small chondrules with sub-milligram mass from the Dhajala meteorite. The all metal ultra high vacuum extraction system provides typical blank levels of ^{4}He, ^{20}Ne, ^{36}Ar and ^{40}Ar that are 100 to 1000 times lower than obtainable from the glass extraction system using conventional resistance/induction heating for gas extraction. Six chondrules of about 0.8 to 0.9 mg mass from the Dhajala meteorite have been analysed by performing 3 to 4 extraction steps using both 1064 nm and 532 nm laser radiations. Though radiogenic ^{4}He and ^{40}Ar show variations of 47% and by factor of 32 among the six chondrules, the cosmogenic ^{3}He and ^{21}Ne vary by only 16% and 30%, respectively. The cosmogenic ^{38}Ar is very high (1.7 to 9 times), as compared to the expected value based on an average cosmogenic $^{21}Ne/^{38}Ar$ ratio of ~ 7. This high value would imply a high Ca content in the chondrules by upto a factor of nine than in the bulk meteorite.

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

Multistage Exposure Records in Meteorites: Evidence for Parent Body Irradiation

Meteorites represent fragments of different asteroids that were ejected into space during collisions and reach the earth due to orbital perturbation after spending millions of years in the interplanetary space. Both during their residence in the parent asteroids as well as in interplanetary space, meteorites are exposed to energetic cosmic rays that can produce stable and radioactive nuclides in them. Several of the recently fallen meteorites have been studied for their chemical characterization and cosmic ray produced radioactivity (^{26}Al, ^{22}Na, etc.), tracks and noble gases. One of the meteorite, Lohawat, belonging to the howardite group was found to have the longest cosmic ray exposure (~110 Ma) in interplanetary space amongst meteorite belonging to this group. Studies of cosmic ray irradiation history of another meteorite, Fermo, suggested that this meteorite has undergone several stages of irradiation including a short duration (~10^4 years) surface exposure as well as a long duration (>10 Ma) deep seated exposure in its parent asteroid followed by an exposure in space for ~9 Ma. The parent body exposure characteristics are inferred from observations of minute traces of noble gases of solar origin and presence of thermal neutron produced ^{82}Kr and ^{128}Xe in this meteorite. These observations provide the first clear evidence for parent body irradiation of a meteorite. This work was carried out in collaboration with scientists from University of Torino, Italy.

(N. Bhandari, S.V.S. Murty, P.N. Shukla, R.R. Mahajan, A.D. Shukla and K.M. Suthar)

EET83309, a Diamond Free Polymict Ureilite

Both monomict and polymict ureilites contain submicron sized diamonds. So far the monomict ureilite ALH 78019 is the only ureilite that has been shown to be devoid of diamonds. In the course of our ureilite studies, we have analyzed the carbon phases of both monomict and polymict ureilites including ALH78019. Based on the combustion pattern of the carbon phase, we have established that the polymict ureilite EET83309 is also diamond free, making it the first such meteorite of polymict class. Most of the carbon in EET83309 is amorphous and hosts noble gases and heavy nitrogen, unlike the case of ALH78019, which has lighter nitrogen. The different nitrogen isotopic compositions of amorphous carbon from these two diamond free ureilites, despite similar noble gas composition, is a reflection of the different physicochemical conditions in the nebula during formation of the C-phases. This work was carried out in collaboration with scientists from the Max Planck Institute für Chemie, Mainz, Germany.

(Vinai K. Rai and S.V.S. Murty)

Nucleogenic Noble Gases: A New Dating Tool for Carbonatite

Carbonatites are enriched in uranium and thorium. In particular apatite from carbonatites is not only rich in U, Th, but also has F upto about 2%. The radioactive decay of ^{238}U, ^{235}U and ^{232}Th generate alpha (^{4}He) particles with sufficient energies to induce (α, n)

reactions on ^{18}O and ^{19}F and generate ^{21}Ne and ^{22}Ne, respectively. If nucleogenic Ne is well retained, one can use U-$^{21,22}Ne$ as potential chronometers. Though nucleogenic ^{21}Ne and ^{22}Ne have been well established, they have not been exploited as chronometers so far. We have analysed Ne and U in an apatite from Hogenekal as a test case. The neon isotopic data (**Fig. 6. 6**) indicate that the neon isotopic ratios $^{22}Ne/^{20}Ne$ and $^{21}Ne/^{20}Ne$ show excesses relative to atmospheric values. As the data points are far above the mass fractionation line (MFL) the excess may be attributed to a nucleogenic origin resulting from alpha induced reactions on oxygen and fluorine. Considering a U content of 15 ppm and the inferred ^{21}Ne excess of 2.72×10^{-10} ccSTP/g, we obtain a U-^{21}Ne age of 2180 Ma. This age is in excellent agreement with the U-fission Xe age of 2150 Ma for this sample, measured during the same experiment, and provide credence to the new chronometer. This work was done in collaboration with scientists from National Geophysical Research Institute , Hyderabad.

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

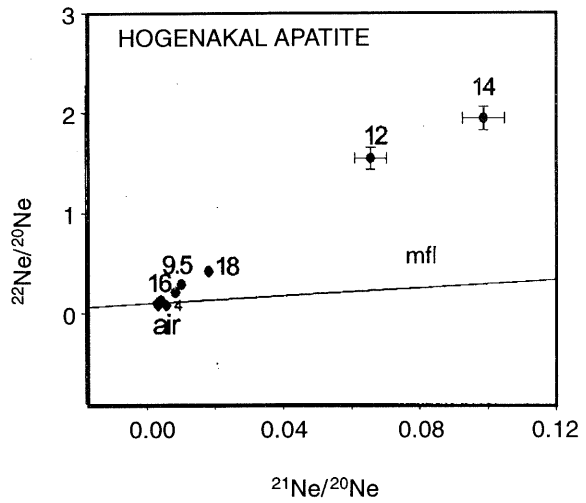


Fig. 6.6 Neon isotopic ratios for various temperature steps for apatites in Hogenakal carbonatite. Numbers indicate temperature in hundreds of centigrades. Trapped ratio for "Air" is also shown. The line labelled "MFL" represents expected trend due to mass fractionation effects.

Permian-Triassic (P/T) Mass Extinction

Our preliminary studies of U and Th in a P/T section from Spiti Valley (Attargoo) has indicated the presence of a reducing environment at the P/T boundary (PTB). A more detailed study of samples from another section from Spiti Valley (Guling section) was carried out to check for an anoxic environment around PTB in the Tethyan regime. The Th/U ratio which is an indicator of redox conditions, is almost constant in the lower Permian but starts decreasing at ~20-30 cm below the PTB in both the sections. Our observations are similar to those reported for other P/T sections across the globe (e.g. China, Alps, Spitsbergen, Greenland, British Columbia and Japan).

Based on various elemental correlation diagrams and rare earth element (REE) studies (e.g. La vs Hf; Hf vs Th; Co-Th-Hf, U vs La and REE patterns) we could not identify any acidic component in our sample that may be attributed to the South China volcanism that erupted around the same time as the PTB. The absence of acidic components in P/T clays from Chinese sections also suggests that the debris from the south China volcanism did not reach the Tethyan regime.

(P.N. Shukla, A.D. Shukla and N. Bhandari)

Evidence for Pre-Deccan Upper Cretaceous Volcanic Activity in Southern India

The felsic volcanics (rhyolites and rhyodacites) of the St. Mary's Islands (SMI), southern India (~13°N), were originally interpreted as a distant outlier of the ~65 Ma Deccan volcanic province of west-central India, comprising dominantly of flood basalts. Later the SMI volcanics were dated at ~ 93 Ma by the K-Ar technique. Precise ^{40}Ar-^{39}Ar dating of the SMI volcanics carried out by us yielded excellent plateau ages (**Fig. 6.7**) with a mean value of 85.5 ± 0.4 Ma (2s). The southern Indian Precambrian terrain is also crossed by numerous mafic-doleritic dyke swarms that range in age from Proterozoic to the latest Cretaceous. Two such regional dykes (a leucogabbro and a felsite) from the Kerala region of southwestern India were dated at ~ 85 Ma. The age for the SMI volcanics obtained by us is also close to the ^{40}Ar-^{39}Ar age 87.6 ± 1.2 Ma (2s) for the Madagascar

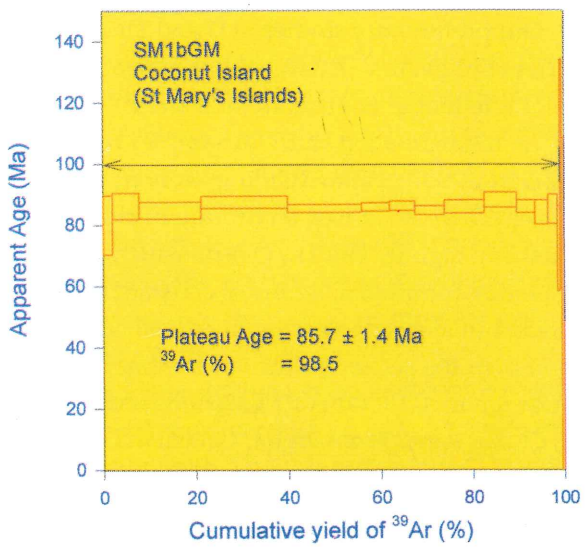


Fig. 6.7 ^{40}Ar-^{39}Ar apparent ages plotted as a function of cumulative fraction of ^{39}Ar released for a sample of St. Mary Island volcanics. The plateau age inferred from the data is also shown.

flood basalt province. Thus, the Madagascar flood basalt province, the SMI volcanics, and the Kerala dykes could represent volcanic activity associated with the breakup of Greater India (India plus Seychelles) and Madagascar, thought to have occurred in the Upper Cretaceous at ~88 Ma.

(Kanchan Pande, Hetu C. Sheth and Rajneesh Bhutani)

The Karnataka Late Cretaceous Dykes: Products of Madagascar – India Breakup Event

Two late Cretaceous mafic dykes located nearly 200 km inland around Huliyardurga, Karnataka state, yield ^{40}Ar-^{39}Ar plateau ages of 90.0±1.0 and 87.5±0.9 Ma, respectively. These Fe-Ti-enriched tholeiites are essentially coeval with at least four other igneous suites widely scattered in southern India, namely, the south and north Kerala dykes, the Agali-Anaikatti dykes of central Kerala-Tamil Nadu and lavas of St. Mary's islands off the west coast of India. The Karnataka Cretaceous dykes are also coeval and compositionally very similar to the Fe-Ti-enriched tholeiitic lavas and dyke around Mananjari, a major phase of Late Cretaceous magmatism along the eastern rifted margin of Madagascar which are believed to be the products of the Marion hot spot that extruded around 88 Ma ago, synchronous to the India- Madagascar break up event. The age and compositional similarities between these Late Cretaceous magmatic rocks from India and Madagascar constitute a clear evidence for extension of the thermal manifestations deep into the Indian peninsula. This work was carried out in collaboration with scientists from National Geophysical Research Institute, Hyderabad.

(Kanchan Pande and T.R. Venkatesan)

^{40}Ar-^{39}Ar Ages of Deccan Traps, Bombay

The Deccan Trap geology of Bombay (Mumbai) differs from the main Deccan flood basalt province in several ways. Very few geological, geochemical and geochronological studies exist on the Deccan geology of Bombay. The basalt of Gilbert Hill, Andheri, occupies a special place in Bombay geology on account of its spectacular columnar jointing, more than 50m high, and this has been designated a National Geological Monument by the Geological Survey of India. We have obtained a ^{40}Ar-^{39}Ar plateau age of 60.5 ± 1.2 Ma (2σ) for the Gilbert Hill basalt, the first such age on any Deccan basalt from Bombay. This basalt appeared to have erupted considerably later (~ 6 million years) than the lower part of the Western Ghats lava pile.

We have also determined ages of 60.4 ± 0.6 Ma and 61.8 ± 0.6 Ma (2σ) for two Deccan Trap trachytes from Manori and Saki Naka, Bombay, situated in the tectonized Panvel flexure zone along the western Indian rifted continental margin. Our results provide clear evidence that (i) these trachytes are of Palaeocene age and substantially younger than the lower part of the main flood basalt sequence exposed in the Western Ghats, which precedes the K-T Boundary in age, and (ii) the formation of the Panvel flexure along the west coast must have taken place subsequent to ~ 60 Ma. Our data for the Mumbai Deccan Trap samples place a lower limit of 8 Ma for the total duration of Deccan volcanism.

(Kanchan Pande, Hetu C. Sheth and Rajneesh Bhutani)

Facilities

Computer Centre

The Computer Centre is equipped with five IBM RS-6000/580 servers. These servers are interconnected with FDDI Network forming a powerful cluster for computing. This cluster is further connected to six X-stations and more than 200 PCs and few workstations distributed throughout the Laboratory. It is also connected to the INTERNET via a fast leased line. Thus full connectivity has been provided to users all the time from anywhere in the main premises and the Thaltej Campus. Application Software Libraries have been provided to cater to the need of scientific community in performing the mathematical and numerical calculations and visualization of data. The provision of making colour slides, prints and video tapes is available. The centre provides the consultations and other facilities including archival of file systems, system security, authorisation, updating the system softwares, third party softwares and public domain softwares. It also maintains internet connectivity and the local area network.

(P. S. Shah, G. Dholakia, M. Patel, J. Trivedi & R. Shukla)

Library

The aim of PRL Library is to keep track of the latest developments in science and technology and to make relevant information available to scientific community. The methods of information acquisition and dissemination are changing rapidly due to innovations in information technology. PRL library tries to keep space with contemporary technology for benefit of information seekers. PRL library consists of rich collection of books, journals, reports, data and articles in various forms. The total collection exceeds 50000 items with more than 16000 books and 30,000 bound volumes of journals. Other collection includes reports, doctaral thesis, videos, CDs, PRL publications like reprints and technical notes. Besides circulation of books, journals and other documents, library provides to the readers services like photocopying, reference services, internet search, SDI services and retrospective literature search, inter library loan, translation and procure books for individual book-grants etc.

For the year 2001 library has subscribed to 175 journals and periodicals. About 250 books were added to the collection apart from large number of other documents like reports, data and maps for scientific use. PRL library also subscribes to searchable databases namely STN and Uncover to get full articles from 18000 other journals on request to satisfy specific queries of the users. The articles are received by FAX for quick delivery to the users. Under Inter Library Loan (ILL) more than 250 requests were served for which PRL library works closely with other libraries in Ahmedabad as well as other science and technology libraries.

An important addition to the library services this year has been stating of ScienceDirect service from Elsevier Science. Under this service readers can search across journals via abstracts database which contains abstracts from core journal in the major scientific disciplines with easy menu driven search forms with facility to down load articles from select publishers or can order the same via document delivery service.

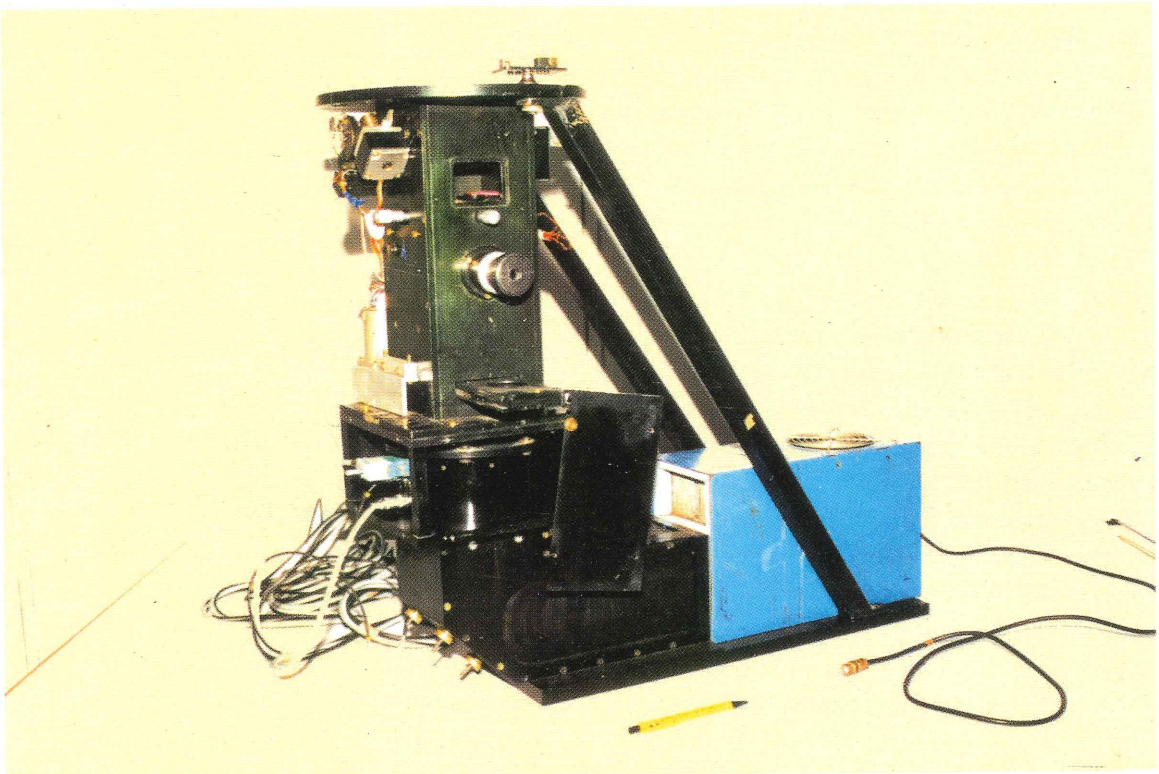
During the year more than 4000 books and journals were issued and more than 4,50,000 photocopies were supplied using in-house facility and external resources. The library extensively uses computerization to serve the readers.

For easy access, electronic resources are linked through library home page which acts as front end to the users.

(S. M. Pradhan, U. Ghiya & N. Anilkumar)

Workshop

The workshop provides design and fabrication support to various experimental divisions of PRL. A scientific instrument designed, fabricated and assembled in-house, requires very high precision for various components and subassemblies. Using the facilities available with us which include a precision CNC lathe machine, radial drill machines, milling machines, various types of welding machines, etc., the required accuracy and very good surface finish is being achieved consistently. Some of the major works carried out during the year are listed below:



- A Central-fringe scanning Fabry-Perot Spectrometer (CFPS) for Astronomy and Astrophysics division was redesigned and fabricated. The CFPS has a collimator, FP-Etalon, filters, calibration facility, adjustable aperture with x-y movement, and a thermoelectric cooling unit along with a PMT for photon counting. The old design had a problem of flexure due to its longitudinal dimensions (required to accommodate the optics) and its weight. The new design uses an L shaped mechanical structure with modified optics. All the parts were fabricated to hold / adjust all the optical components, with required accuracy. The new instrument is now being used for observations at 1.2m IR Telescope at Mt. Abu.
- A lot of design work on Solar X-ray Spectrometer (SOXS) experiment, for Astronomy and Astrophysics division, has been done during the year in consultation with SAC-Ahmedabad and ISAC-Bangalore.
- The work of alignment and balancing of Solar Telescope at Udaipur (USO), was completed during the year. For this screws required for the balancing of the telescope were completely redesigned. The screws were made using the CNC machine. With these new screws and adjusting balancing weight, the telescope movement is now very smooth. A field stop and new cover were also fabricated and installed.
- A Cathode Wheel for Accelerator Mass-Spectrometer (AMS), for Earth Sciences and Solar Systems Division, was designed and fabricated using special grade Aluminium material. The wheel is designed to accommodate 40 aluminium holders (cathode) with very high angular accuracy. The wheel is loaded on to AMS with cathode containing the samples.
- Optical Alignment Instrument (OAI), for Planetary Atmospheres and Aeronomy division, was

designed and fabricated for LIDAR experiment. The OAI is designed to have three axes (Azimuth, Rotary and Elevatory) of freedom for alignment. The Azimuth, Rotary and Elevatory movement has a range of 0-20 degree, ± 15 degree and ±15 degree respectively with an accuracy of 0.5 degree. Steel balls and fine thread screws are used for obtaining the Azimuth movement while the Rotary and Elevatory movements are obtained by use of fine thread screws.

In addition to the above work, a large number of jobs from different groups/divisions, which includes precision machining (turning, boring, shaping, milling, drilling, grinding etc), sheet metal and structural fabrication, painting, modifications and installation of experimental set-up, were completed. Regular maintenance work, on some of the machines in the workshop, was carried-out. Support to USO, and Mt. Abu observatory was provided as required from time to time during the year.

(G. P. Ubale, H. R. Vaghela and their team)

Engineering Services

The Engineering Services render all technical services pertaining to civil engineering works and related building and laboratory services such as electrical, air-conditioning, internal telephone system, elevators, etc. Maintenance of all the laboratory, office and residential buildings in various campuses is looked after by the section. These include architectural planning, designing, estimating and execution of various civil works, landscaping, horticultural development, interiors & furnishings of buildings & structures of all the six Campuses – PRL main campus, Staff Quarter Campus, Thaltej Campus, Mt. Abu Campus, Udaipur Campus & Vikramanagar Staff Quarter Campus.

Site preparation works were executed for installation of sophisticated research equipments by meeting with all special requirements. The major work undertaken during the year has been :

- The old passenger lifts are being replaced with new pair of lifts of modern design which are energy efficient and thus expect to give saving in electricity.
- The work on modification of laboratory space in room no.370 has been taken up and also the sub millimeter laboratory in room no.251.
- Power factor correction capacitors are also been installed with an aim to improve the load factor & saving in electrical charges.

(R. N. Mishra, D. H. Jokhakar, K. V. K. Reddy, S. K. Bhavsar and their team)

Honorary Fellows & Professors at PRL

Honorary Fellows at PRL

Professor Hannes Alfvén

Professor J.E. Blamont

Professor S. Chandrasekhar

Acad. V.L. Ginzburg

Professor B. Rossi

Professor J.B. French

Professor A.M.J. Tom Gehrels

Professor D. Lal

Professor P.R. Pisharoty

Professor M.G.K. Menon

Professor S. Dhawan

Professor U. R. Rao

Prof. P. Crutzen

Prof. K. Kasturirangan

Prof. A. Hewish

Honorary Professors at PRL

Professor Yash Pal

Professor S. P. Pandya

Professor R. K. Varma

Professor B. L. K. Somayajulu

Academic Faculty Of PRL

Academic Faculty of PRL

Name	Specialisation	Academic Qualification
Prof. G. S. Agarwal FNA, FASc, FNASc	Quantum Optics, Nonlinear Optics and Laser	Ph D Rochester Univ. (1969)
Prof. N. Bhandari FASc, FNASc	Planetary Physics	Ph D TIFR Bombay Univ. (1967)
Prof. S. Krishnaswami FNA, FASc, FNASc	Aqueous Geochemistry and Nuclear Oceanography	Ph D TIFR, Bombay Univ. (1974)
Prof. A. R. Prasanna	General Relativity and Astrophysics	Ph D Poona Univ.(1970)
Prof. D. P. Dewangan	Atomic and Molecular Physics	Ph D Calcutta Univ. (1973)
Prof. J. N. Goswami FASc, FNASc	Solar System Studies (Pre - Solar Processes)	Ph D PRL, Gujarat Univ. (1978)
Prof. V. K. B. Kota	Nuclear Physics	Ph D Andhra Univ.(1977)
Prof. A. S. Joshipura FASc	Particle Physics	Ph D Bombay Univ. (1979)
Prof. A. K. Singhvi FASc, FNASc	Palaeoclimatology and Geochronology	Ph D IIT, Kanpur (1975)
Prof. S. K. Bhattacharya FASc	Isotope Geochemistry	Ph D PRL, Gujarat Univ. (1980)
Prof. V. B. Sheorey	Theoretical Atomic Physics and Non linear Dynamics	Ph D Univ. College, London Univ.(1968)
Prof. S. D. Rindani	Particle Physics	Ph D IIT, Bombay (1976)
Prof. Harish Chandra	Ionospheric Studies and Dynamics of Middle Atmosphere	Ph D PRL, Gujarat Univ. (1970)
Prof. B. G. A. Rao	Spectroscopic Diagnostic in Astrophysical Plasmas	Ph D PRL, Gujarat Univ. (1978)
Prof. P. Venkatakrishnan	Solar Physics	Ph D, Bangalore Univ. (1984)
Dr. Hemant H. Dave	Laser Spectroscopy and Space Instrumentation	Ph D, Univ. of Lowell, Mass., USA (1980)
Dr. S. P. Gupta	Electrodynamics of Middle Atmospher	Ph D PRL, Gujarat Univ. (1971)
Dr. R. E. Amritkar	Nonlinear Dynamics & Chaos	Ph D IISc, Bangalore (1978)
Dr. U. C. Joshi	Star Formation, AGNS and Comets	Ph D Kumaun Univ. (1981)
Dr. H. S. S. Sinha	Upper Atmospheric and Ionospheric Studies	Ph D PRL, Gujarat Univ. (1977)

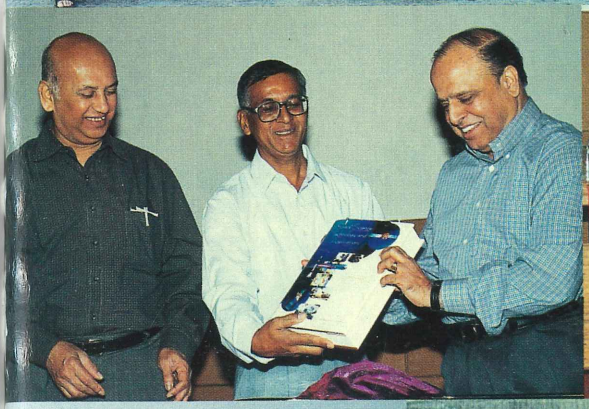
Name	Specialisation	Academic Qualification
Dr. Utpal G. Sarkar	Particle Physics	Ph.D Calcutta Univ. (1984)
Dr. S. K. Gupta	Geophysics, Hydrology	Ph D IIT, Bombay (1974)
Dr. P. N. Shukla	Geochemistry	Ph D IIT, Kanpur (1977)
Dr. D. R. Kulkarni	Computational Physics	Ph D M S Univ (1972)
Dr. P. Sharma	Geophysics and Hydrology	Ph D PRL, Gujarat Univ. (1977)
Dr. N. M. Ashok	Infrared Observations	Ph D PRL, Gujarat Univ. (1983)
Dr. T. Chandrasekhar	Optical & Infrared Astronomy	Ph D PRL, Gujarat Univ. (1982)
Dr. N. Nagesha Rao	Theoretical Plasma Physics	Ph D PRL, Gujarat Univ. (1982)
Dr. Shyam Lal	Atmospheric Chemistry of Trace Gases	Ph D PRL, Gujarat Univ. (1982)
Dr. R. Ramesh	Isotope Geochemistry	Ph D PRL, Gujarat Univ. (1984)
Dr. A. Jayaraman	Atmospheric Aerosols and Radiative Studies	Ph D PRL, Gujarat Univ. (1985)
Dr. Hari Om Vats	Ionospheric Physics and Radio Astrophysics	Ph D PRL, Gujarat Univ. (1979)
Dr. M. M. Sarin FASc	Geochemistry and Oceanography	Ph D PRL, Gujarat Univ. (1985)
Dr. S. V. S. Murty	Isotope Cosmochemistry	Ph D IIT, Kanpur (1981)
Dr. A. K. Ambastha	Solar Plasma Physics	Ph D PRL, Gujarat Univ. (1981)
Dr. J. Banerji	Laser Physics	Ph D City Univ.(New York)(1982)
Dr. K. S. Baliyan	Atomic Physics & Atomic Astrophysics	Ph D Roorkee Univ.(1986)
Dr. Sai K Iyer	Large Scale Structure, General Relativity	Ph D Washington Univ. USA (1987)
Dr. Kanchan Pande	Geology, Geochronology	Ph D PRL, Gujarat Univ. (1990)
Dr. Ashok K Singal	Radio Astronomy	Ph D TIFR, Bombay Univ.(1986)
Dr. D. P. K. Banerjee	Astronomy & Astrophysics, High Resolution Spectroscopy	Ph D PRL, Gujarat Univ. (1991)
Dr. K. P. Subramanian	Experimental Atomic and Molecular Physics	Ph D PRL, Gujarat Univ. (1987)
Dr. Syed Aftab Haider	Planetary and Cometary Atmospheres	Ph D Banaras Univ. (1984)
Dr. P. Janardhan	Radio Astrophysics	Ph D PRL, Gujarat Univ. (1992)
Dr. R. Sekar	Upper Atmospheric and Ionospheric Physics	Ph D PRL, Gujarat Univ. (1991)

Name	Specialisation	Academic Qualification
Dr. J. R. Trivedi	Geochronology	Ph D PRL, Gujarat Univ. (1991)
Dr. Subhendra Mohanty	Astroparticle Physics	Ph D Wisconsin Univ. (1989)
Dr. Debi Prasad	Solar Cometary Physics	Ph D PRL, Gujarat Univ. (1990)
Dr. S.C. Tripathy	Solar Physics	Ph D PRL, Gujarat Univ. (1993)
Dr. Rajmal Jain	Solar Physics	Ph D PRL, Gujarat Univ. (1983)
Dr. J. R. Bhatt	Astrophysics	Ph D Gujarat Univ. (1992)
Dr. A. Lakshminarayan	Nonlinear Dynamics & Quantum Chaos	Ph D State Univ.,New York (1993)
Dr. H. Mishra	Strong Interaction Physics & Nuclear Astrophysics	Ph D, Utkal Univ. (1994)
Dr. G. Srinivasan	Cosmochemistry	Ph D, PRL, MS Univ. (1995)
Dr. R. Rangarajan	Particle Physics & Cosmology	Ph D, Univ. of California, Santa Barbara (1994)
Dr. S. Ramachandran	Atmospheric Physics	Ph D, PRL, MS Univ. (1996)
Dr. Varun Sheel	Modelling of Lower Atmosphere	Ph D, PRL, Guj. Univ. (1996)
Dr.(Ms.) N. Srivastava	Solar Physics	Ph D, PRL, Ravi Shankar Shukla Univ. (1994)

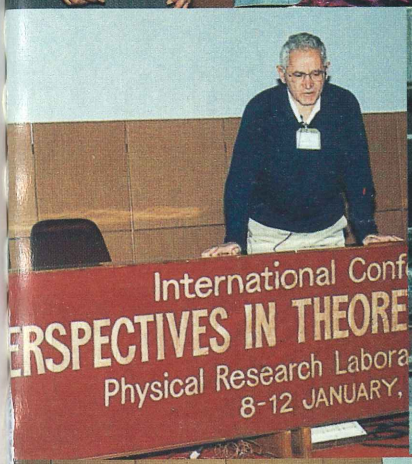
Cover :

vents at PRL

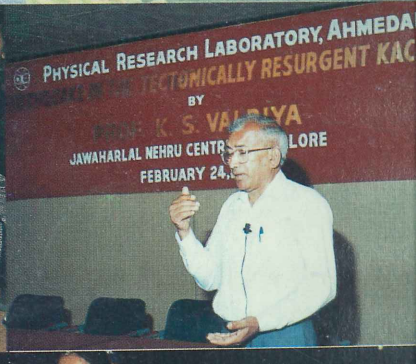

METEORITES, ASTEROIDS AND PLANETS
PHYSICAL RESEARCH LABORATORY, AHMEDABAD

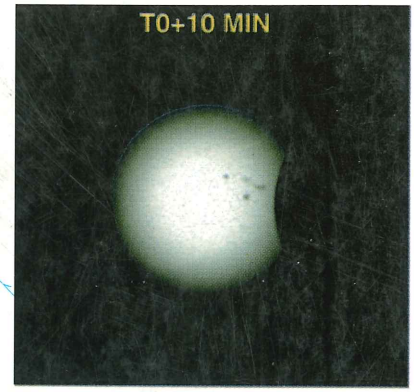


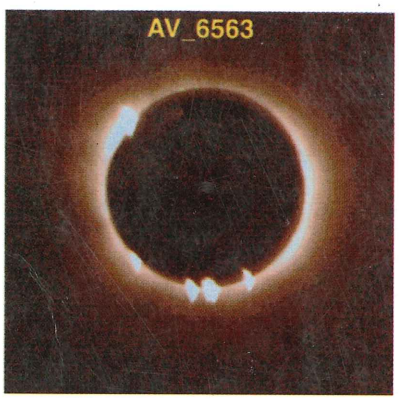

H.CHANDRA
U. R. RAO
K. KASTURIRANGAN
अंतरिक्ष विज्ञान और प्रौद्योगिकी - प्रगति एवं समाज के लिए उपयोग पर संगोष्ठ
भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद
SYMPOSIUM ON
SPACE SCIENCE & TECHNOLOGY - ADVANCES & APPLICATIONS TO SOCIETY
24-25 OCTOBER, 2000
PHYSICAL RESEARCH LABORATORY, A'BAD


International Conf
ERSPECTIVES IN THEORE
Physical Research Labora
8-12 JANUARY,


International Conference on
PERSPECTIVES IN THEORETICAL PHYSICS
Physical Research Laboratory, Ahmedabad
8-12 JANUARY, 2001


PHYSICAL RESEARCH LABORATORY, AHMEDA
BY
JAWAHARLAL NEHRU CENTR
LORE
FEBRUARY 24,



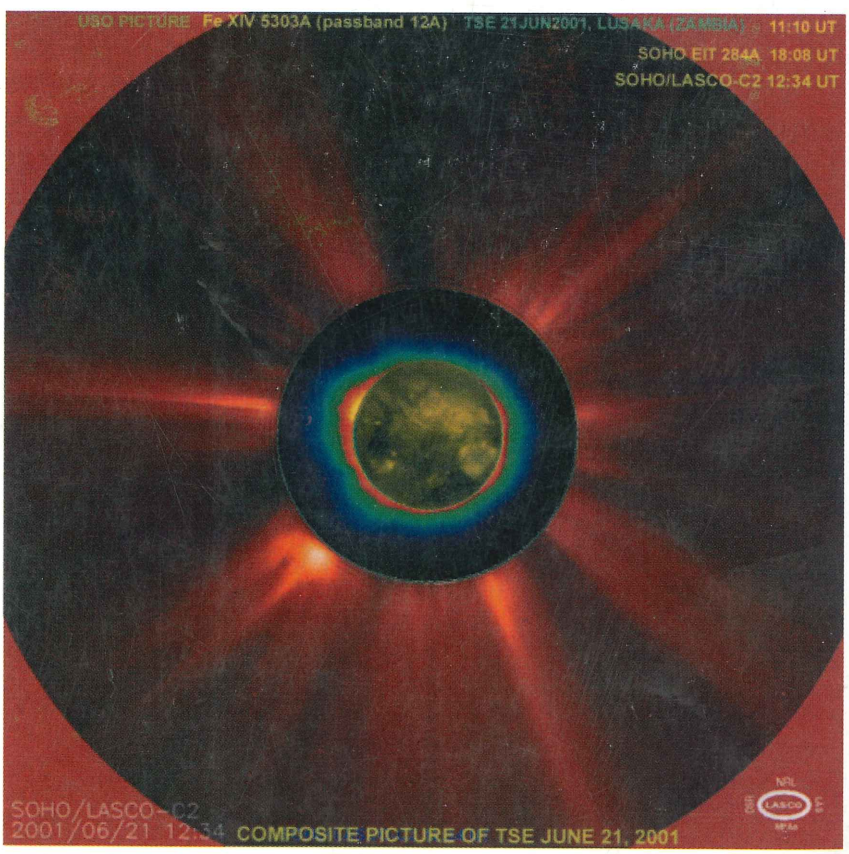


21 जून, 2001 को लुसाका, जाम्बिया से देखा गया पूर्ण सूर्य ग्रहण

1. शूरू होने के **10** मिनट बाद (**09:51 UT** पर) आंशिक प्रावस्था
2. **FeXIV 5303** हरे फिल्टर के द्वारा पूर्णता प्रावस्था के समय परिमंडल (कोरोना)
3. **FeX 6375** लाल फिल्टर के द्वारा पूर्णता प्रावस्था के समय परिमंडल (कोरोना), और
4. **Hα 6563** फिल्टर के द्वारा पूर्णता प्रावस्था के समय परिमंडल (कोरोना)

Total Solar Eclipse of June 21, 2001 from Lusaka, Zambia

1. Partial phase 10 minutes after the first contact, i.e. at 09:51 UT,
2. Totality phase-corona through FeXIV 5303 green filter,
3. Totality phase-corona through FeX 6375 red filter, and
4. Totality phase-corona through Hα 6563 filter.



1. डिस्क - पर (सोहो **EIT 284A** प्रतिबिंब का उपयोग करते हुए),
2. भीतरी परिमंडल (कोरोना) (**5303A** में **USO's TSE** प्रेक्षण, **12A** पास बैंड), और
3. परिमंडल (कोरोना) का विस्तृत श्वेत प्रकाश **(LASCO-C2)** का मिश्रित चित्र

A composite picture of the

1. On-disk (using SOHO EIT 284A image),
2. inner corona (USO's TSE observation in 5303A, passband 12A), and
3. extended white light corona (LASCO-C2)