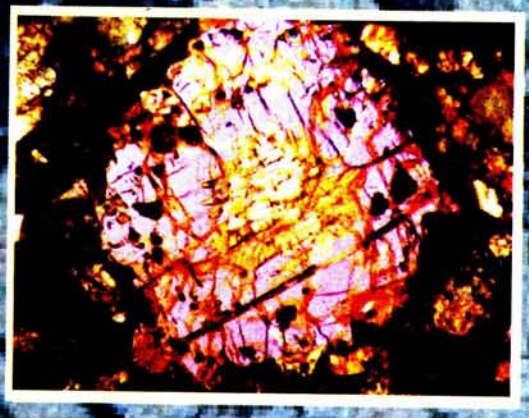
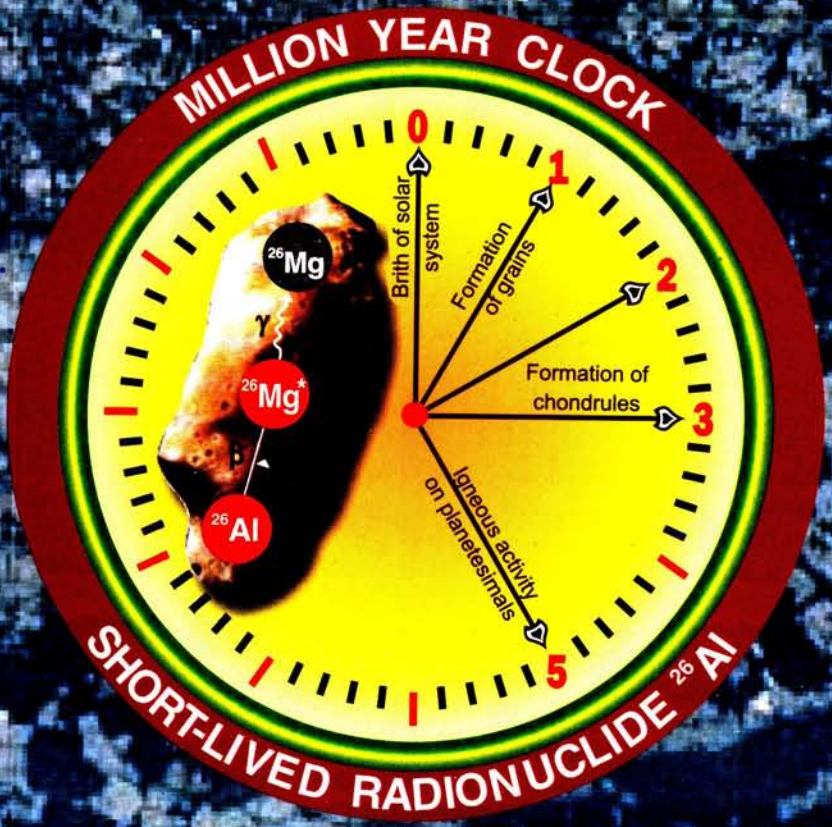
भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद
PHYSICAL RESEARCH LABORATORY, AHMEDABAD.

वार्षिक रिपोर्ट
ANNUAL REPORT
1998-99





^{26}Al - A heat source for early melting of planetesimals


Centre for Space Science & Technology Education (CSSTE - AP)
Joint Valedictory Function of the Post Graduate Courses
in
Satellite Meteorology and Global Climate & Space Science
Physical Research Laboratory, Ahmedabad
November 28, 1998

वार्षिक रिपोर्ट
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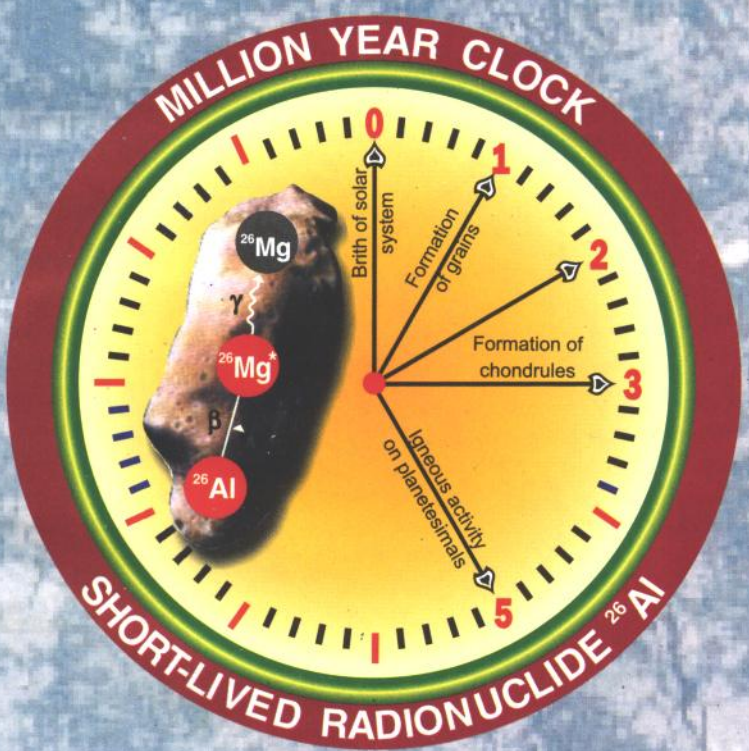
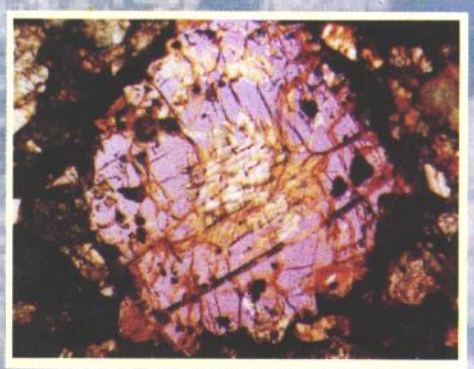
मिलियन वर्ष घड़ी द्वारा दर्शाया गया आरंभिक सौरतंत्र की घटनाओं का समयमान। यह उल्कापिंड नमूनों में अल्पजीवी न्यूक्लिड ^{26}Al के रेकार्डों : उच्चतापसह अन्तर्वेशन (CAIs) - सौरतंत्र में बने प्रथम पिंड (इनसैट के ऊपर का चित्र), बाद में बने उच्चतापसह सिलिकेट कॉन्ड्यूल (मध्य चित्र) और पिपलिया कलां उल्कापिंड (निचला चित्र)- एक बार के पिघले ग्रहाणु के टुकड़े पर आधारित है। इसकी पृष्ठभूमि में पिपलिया कलां के चमकीले हिस्से का बिंब है। इस नमूने के आयनप्रोब अध्ययन इस बात की पुष्टि करते हैं कि ^{26}Al के ^{26}Mg में क्षय होने के कारण इसने ग्रहाणुओं के आरंभिक गलन के लिए ताप स्रोत्र के रूप में कार्य किया।





Time-scales of events in the early solar system depicted by a million year clock, based on records of the short-lived nuclide ^{26}Al in meteorite samples: refractory inclusions (CAIs), the first solids to form in the solar system (top photograph of the inset), later formed refractory silicate chondrules (middle photograph) and the meteorite Piplia Kalan (bottom photograph), a fragment of an once molten planetesimal. The background is an image of a polished section of Piplia Kalan. Ion probe studies of this sample confirm that decay of ^{26}Al to ^{26}Mg acted as the source of heat for the early melting of planetesimals.

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

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Council of Management 1998-99

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Contents

Introduction

The year 1998-99 is a momentous year. As we near the end of the millennium, a new century and a new era is beckoning us. This annual report would be the last in this century as we step into the threshold of a new millennium; a millennium which would hopefully be studded with stunning and brilliant discoveries. On one side there is pride of our achievements and on the other there is hope of adorning the coming century with scientific excellence. We are proud that the laboratory which started as a centre for space physics and later became the cradle of India's Space Programme, has grown in leaps and bounds encompassing disciplines like astronomy and astrophysics; planetary and space sciences; earth sciences; theoretical physics and nonlinear dynamics and computational sciences; and laser physics and quantum optics.

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 papers have been published, of which one hundred and twelve were in high impact journals. During the year our scientists have convened eight symposia/ workshop, two of which were organised at Nagoya, Japan during the 32nd COSPAR meeting. Also our scientists continued to participate actively in national and international conferences with large number of invited and contributed presentations. During the reporting year one hundred and eighty one papers were presented out of which sixty six were invited review talks and ninety six were presented in international conferences. At present PRL has thirty one research scholars and nineteen post-doctoral fellows working in various disciplines. Nine Ph.D. theses were submitted. The topics covered were as diverse as studies of classical novae and related objects; solar magnetic and velocity fields; ionospheric irregularities; measurements of electron scattering cross-sections; fluorescence studies using laser; nitrogen in Earth's mantle and the lesser Himalayan sediments. A summary of scientific achievements is given on page 5 .

One of the highlights of our activities was the first **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, held at the Physical Research Laboratory, Ahmedabad during June-November, 1998. The course was of one year duration and was organized in two phases of six months each. The Phase I, which was completed at PRL in November, 1998, had four modules spread over two semesters. The scientific topics covered in these four modules were (1) Atmospheric Science, (2) Ionosphere and Solar Terrestrial Interactions, (3) Instrumentation, Techniques and Data Processing and (4) Modelling. Phase II is being executed in the home country of the participants. On the successful completion of the Phase-2, which involves carrying out a 6 months project in the home country and writing a thesis, the participants may be awarded the degree of M.Sc. (Tech.) by the Andhra University, Waltair, India subject to the fulfillment of the University's eligibility criteria. The faculty for this course included experts in different fields drawn from India and abroad.

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 *Shanti Swarup Bhatnagar Prize* of the Council of Scientific and Industrial Research; *(INSA) Medal for Young Scientists* of Indian National Science Academy; *Associate* of Indian Academy of Sciences; the *Hari Om Ashram Prerit Vikram Sarabhai Research Awards* of Physical Research Laboratory; *Alfred O. Nier Prize* of the Meteoritical Society and *the Young Scientist Award* of International Union for Radio Science (URSI).

The laboratory had intensive collaboration in various national and international programme. The programme on Trace Gases in Atmosphere under the International Atomic Energy Sponsored Programme is almost near completion. The programme involved the measurement of concentrations and isotopic ratios in trace gases in air samples from a coastal station of India. The results of analyses carried out since 1993 show the effect of South-west monsoon and Northeast Monsoon on strengthening of sources and sinks of trace gases in this region. Our participation in the Indian Ocean Experiment (INDOEX) has been intensified with quite a few cruises to the Indian Ocean to assess the significance of sulfates and other continental aerosols for global radiative forcing. Another

international collaboration, Planetary Scale Mesopause Observing System (PSMOS) has been initiated to understand the effects of gravity waves and their interactions with large scale global wave phenomena in mesosphere. In addition to the Global Oscillations Network Group (GONG), PRL scientists are also participating in the Whole Sun Month Campaign to study the Sun for one full solar rotation and in a joint Indo-Russian collaboration on VLBI Studies of Extragalactic Radio Sources using the Ooty Radio Telescope and the European VLBI network.

In the national front our scientists are involved in the development of a national facility of Accelerator Mass-spectrometry in Bhubaneshwar in cooperation with the Institute of Physics, Bhubaneshwar. The facility will be extremely valuable to measure minute amount of radio-carbon activity in natural samples and can be used for dating and other applications in Earth Sciences. The Thermoluminescence laboratory of PRL is participating in a multi-institutional joint programme to delineate the past history of Thar Desert from palaeoclimate point of view. The laboratory's involvement in the national programme on Land Ocean Interaction in the Coastal Zone (LOICZ) has picked up pace with a few field campaigns to the Godavari River System. In another multi-institutional programme, the Indian Solar Terrestrial Energy Programme, the first phase has been successfully completed with the identification of dispersive nature in the Doppler velocities of ESF irregularities. The second phase which aims to understand the longitudinal variabilities in ESF has commenced. The laboratory has recently initiated a program of all sky optical imaging of gravity wave parameters from the unique mountain site of Hanle (39°N, 78°E, 4468m altitude) where the Indian Institute of Astrophysics has set up a 2m optical telescope. The mesospheric optical emissions, in a number of wavelengths, will be imaged to yield information on horizontal and vertical scale sizes, propagation characteristics, seasonal variation etc. of gravity waves.

Prof. Gordon G. Shepherd, Distinguished Research Professor, York University, Canada visited PRL as the twenty first Vikram A. Sarabhai Professor. During his visit he gave few lectures in UN school and a colloquium on *The Influence of Dynamics on Lower Thermospheric Atomic Oxygen Concentrations*. **Prof. M. R. Kundu** from University of Maryland visited PRL as the twenty second Vikram A. Sarabhai Professor. He gave five lectures and a popular lecture on *Storms on the Sun and Space Weather*. **Prof. Oriol Bohigas** from Orsay, France visited PRL as the twenty third Vikram A. Sarabhai Professor. During his visit he gave four lectures and a colloquium on *Quantum Chaos and the Unreasonable Effectiveness of Mathematics in the Natural Sciences*.

On the occasion of the completion of fifty years of our laboratory in 1997, the Council of Management has established the **K. R. Ramanathan Professorship** to honour Prof. K. R. Ramanathan, the Founder Director of the Physical Research Laboratory. **Prof. V. Ramanathan** Director, Centre for Atmospheric Sciences and Centre for Clouds, Chemistry and Climate, Scripps Institute of Oceanography, University of California, San Diego, USA visited PRL as the first K. R. Ramanathan Professor. During his visit he gave five lectures and a popular lecture on *Global Warming : Role of the Indian Ocean and the Sub-Continent.*

Prof. N. Kumar, Director, Raman Research Institute; President, Indian Academy of Sciences delivered the thirteenth Prof. K.R. Ramanathan Memorial Lecture entitled *Waving through Randomness at Maximum Entropy*. **Prof. Madhav Gadgil**, Professor, Centre for Ecological Sciences, IISc, Bangalore delivered the fourteenth Prof. K.R. Ramanathan Memorial Lecture entitled *Western Ghats : A Lifescape*.

Physical Research Laboratory honoured six distinguished scientists at a glittering investiture function on the occasion of the Vikram Jayanti. **Dr. S. Varadarajan, President, Indian National Science Academy** graced the celebrations and gave away the Hari Om Ashram Prerit Vikram Sarabhai Research Awards and the PRL Award. Five distinguished scientists received the Hari Om Awards and one received the PRL Award.

In its endeavour to promote research in space science and technology and to motivate young persons to take up space science as their career, the Science and Engineering Research Council (SERC) of the Department of Science and Technology, Government of India, has sanctioned five schools on Upper Atmospheric Phys-

ics. The **fourth school** was held at the Physical Research Laboratory, Ahmedabad from 6 - 29 April, 1998 **on Electromagnetic Probing of the Upper Atmosphere**. About 45 candidates including fresh Ph. D.s and those working for Ph. D. in Upper Atmospheric Studies were selected from various universities and research institutes in India to attend the school. The course covered a wide range of experimental techniques for upper atmospheric studies involving electromagnetic probing as well as in-situ rocket and satellite-borne techniques. The speakers mainly focussed on the principles, instrumentation and state of the art developments in their respective areas. Newly emerging techniques such as tomographic imaging of the ionosphere, optical aeronomy and radar interferometry were emphasized and their vast potential exposed. These courses were given by eminent scientists chosen from different universities and various research institutes in India. The visit of the participants to the various experimental facilities such as Udaipur Solar Observatory (USO), Mt. Abu, Rajkot IPS Station and hands on job tutorials and lab demonstrations added a new dimension to the course.

A Workshop on High Energy Astrophysical Plasma: Radiation Processes in Astrophysical Plasma was organised to discuss and review the latest development of the subject and also to initiate and develop a co-ordinated and collaborative research activities in this field. The workshop was primarily open for Ph. D. students who are engaged in research, lecturers/researchers from University Departments and National Laboratories. There were about 15 students and about 10 speakers including the special lectures in the afternoon session.

In view of the fact that number of physicists in the country are actively involved in unravelling the Physics of Neutrino, it was decided to have focussed discussions on recent developments in this field. With this view in mind a discussion **Meeting on Recent Developments in Neutrino Physics** was held at PRL during 2 - 4 February 1999. To have focussed discussions, the participation was limited to active workers in the field. The meeting concentrated on (1) in-depth discussion of recent experiments, (2) their implications in understanding neutrino masses and (3) future prospects.

The Laboratory organized a two day meeting on **Current Trends in Plasma Physics** during 9-10 February, 1999. The main objective was to review and discuss recent developments in space and astrophysical plasmas and also some basic plasma processes. Leading experts in these fields in the country were invited. In all, there were 44 registered participants. An interesting session of the meeting was a panel discussion on 10 February 1999. Prof. R. K. Varma initiated the discussion whether some important problems could be identified where workers of space physics, astrophysics and plasma physics could use their expertise to solve them. In addition, there was a popular evening talk by Prof. A. Sen of Institute of Plasma Research, Gandhinagar, explaining how diverse, rich biological behaviours such as the gait of various animals, synchronization of thousands of flashing fireflies and also some natural phenomena like phase transitions in solids could be reproduced by some simple models of coupled nonlinear harmonic oscillators.

The Science and Engineering Research Council (SERC) of the Department of Science and Technology, Government of India, has formulated a five year cycle of summer winter schools in Lasers, Optics and Atomic and Molecular Physics. The **first school** in this cycle was held at the Physical Research Laboratory, Ahmedabad from February 15 to March 7, 1999 **on Atoms and Molecules in Intense Fields**. About 35 participants including fresh Ph. D.s and those working for Ph. D. in Atomic and Molecular Physics have been selected from various universities and research institutes in India to attend the school. The courses being offered included atoms and molecules in weak, static external fields, Rydberg atoms in external static fields, physics of high power lasers, atoms and molecules in intense fields, QED and relativistic effects and resonant processes in intense fields. These courses were given by eminent scientists chosen from Indian and foreign universities and various research institutes in India.

An Instrumentation Course for College Teachers was conducted at PRL during May 4-22, 1998. About 20 participants from various colleges of Gujarat State attended the course. The course contents were based on Optical, Electronic and Vacuum Instrumentation. There

were about 40 lectures covering topics like optical instrumentation; laser and fibre optics; semiconductor devices and analog circuit; signal processing, digital electronics and computers and vacuum techniques and instrumentation. About 7 projects/experiments were arranged in PRL and Thaltej campus. There were three special sessions for discussions during each week. Participants took active interest and faculty members worked hard. On the whole it was a fruitful venture.

As a part of implementation and progressive use of Hindi in PRL, the **Hindi Week** was celebrated at PRL from September 14 - 19, 1998. The highlights of the celebrations included word quiz, essay, elocution, poetry and recitation competitions, including self written poetry and Antakshari. All staff members alongwith their families were invited in some of the programmes to make this celebration attractive. The special attraction of this year's celebrations was lectures by two eminent personalities - one by **Prof. Ambashankar Nagar**, Chairman, Gujarat Hindi Sahitya Parishad who gave the inaugural lecture, the other was by **Prof. Rama** of Tata Institute of Fundamental Research (TIFR), Mumbai who gave a very interesting talk on *Panch Ratno Ki Kahani, Meri Jubani, Pani hi Pani*.

The **National Science Day** was organised on February 27, 1999 at the Physical Research Laboratory in association with the Indian Physics Association (IPA) and Indian National Science Academy (INSA), Ahmedabad Chapter. Science Quiz, both written and oral, popular science lectures and video shows formed part of the programme. The science quiz was open to students of stds. IX and X from schools all over Gujarat. One hundred and thirty two students participated in the written science quiz. Starting from last year, the laboratory has instituted five **PRL Scholarships** from the *Aruna Lal Endowment Fund* established by Prof. D . Lal, Honorary Fellow and former Director, PRL. Five students were selected. PRL also continued the scholarships to the five recipients of 1998 PRL Scholarships for their excellent performance in science and maths in their schools. All the ten students were awarded Rs. 3000/- per year. The scholarships are for three consecutive years provided the students continue to study in science stream with high academic record.

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 S Agarwal

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;

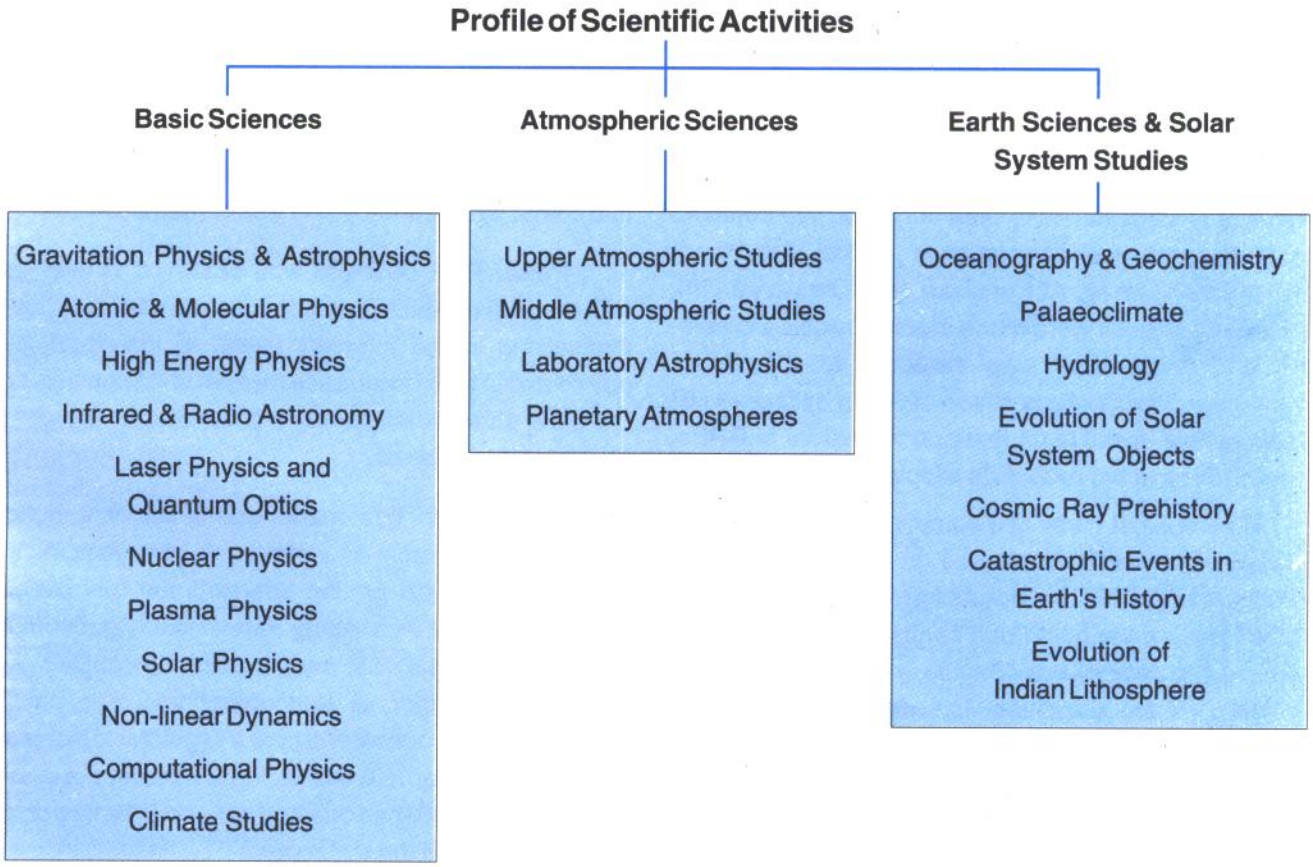
vi. Earth Sciences and Solar System Studies.

The chart below profiles the scientific activities.

Some of the important research contributions are summarised.

Astronomy and Astrophysics

The division's research programme covers a wide spectrum of topics in astronomy starting from solar physics, interplanetary medium, cometary physics to stellar physics (star formation and late stages of stellar evolution) to extragalactic objects: star burst galaxies and active galactic nuclei (AGNs). The Astronomy and Astrophysics Division operates an Infrared Observatory at Mt. Abu (MIRO) housing a 1.2m infrared telescope equipped with world class state-of-the-art back-end instruments such as IR camera (NICMOS-3), thinned back illuminated CCD camera, high resolution Fabry-Perot Spectrometer, Optical and IR polarimeters, high speed dual channel IR photometer, a grating spectrograph etc. Majority of the back-end instruments were developed in-house. For simultaneous imaging in optical and near IR, a two-channel hybrid camera combining a CCD camera and the NICMOS-3 is being developed. Udaipur Solar Observatory (USO), equipped with modern instruments is a premier facility in the country in the area of solar physics. The USO is also participating in the GONG project which aims to study the solar interior using Helioseismology. It has a proposal for inclusion of a solar X-ray spectrometer (SOXS) payload on



on satellite platform in near future and work in this direction has already been initiated. Similarly, efforts for flying the CZT detector on M-100 rocket to measure the break and double power-law in the spectrum of a solar flare, specially during its decay phase are also in progress. Improvisation in the existing facilities at Udaipur Solar Observatory to obtain synoptic observations of the Sun will be undertaken soon to put it as front-line observing facility for next solar maximum and beyond.

The key research areas continue to be the study of AGNs and star forming regions in our galaxy and star burst galaxies and late stages of stellar evolution. An important finding is the detection of simultaneous increase in degree of polarization in visual region and Gamma ray flux at Tev and Pev energies through detection of Cerenkov radiation in Mrk 501. Co-ordinated observations at visual region were carried out using PRL polarimeter on MIRT and at gamma ray using TACTIC-BARC facility at Mt.Abu. Such observations are rare and are extremely important to put constraints on the models. Catching Gamma ray bursts (GRBs) via follow up in optical and near IR bands is one of the hottest topics in astronomy these days. Due to the accurate localization of GRBs by Beppo SAX, optical & IR observations of the after glow are possible. The only constraint is that the follow up observations must start within hours of the detection of GRB as these fade very fast. We detected successfully one such phenomenon - optical after glow of GRB 990123 from Mt. Abu on the night of January 24/25, 1999. Observations were made in I-band with CCD camera, and the source was detected at a level of 20.8 I-mag. Simultaneous observations in optical and IR are extremely useful to understand the nature of GRBs. Keeping this in mind AAD is developing a hybrid camera.

A multi-band study of a sample of twenty starburst galaxies was carried out, based on CCD imaging data from the 1.2m MIRT. The morphology of the galaxies was studied through various broad bands and Hα-filterband. Except in the case of Mrk 439, the line emission and the blue regions are coincident indicating that the same episode of star formation is responsible for both processes. Isophotal twist were detected in all the SO's/E's galaxies in the sample. A strong dust lane was found in Mrk449. Secondary bars are detected in Mrk 213 and Mrk 1194. To understand the underlying structure of starburst galaxies, observations of more than 50 galaxies have been made in H-band (1.65 micron) using IR camera (NICMOS-3).

Another interesting result is the finding of emission from molecular hydrogen v = 1- 0 s(1) vibrational line at 2.122 micron from RNO91, a T Tauri star. Observations were made on the 1.2m MIRT using NICMOS grating spectrometer. The asymmetrical emission extends spatially upto 9 arcsec in the NS direction and the asymmetry is attributed to tilted disc around the star that partially obscures the northern flow. On the basis of [OIII] 5007 A line observations of a planetary nebula NGC 4361, using Imaging Fabry-Perot spectrometer, quadrupolar nature of the nebula is detected.

Near IR observations of Comet Hale-Bopp at J, H and K bands, carried out at 1.2m MIRT on several nights during pre - and post-perihelion phase, showed substantially higher T_{eff} than the equilibrium black body temperatures. The ratio of colour temperature to the BB temperature, also called superheat(s) was found to be 1.86 in the post-perihelion phase, which in turn imply the presence of large fraction of small hot grains of size < 0.5 micron, at least for a short period around perihelion. This is in agreement with the result obtained in polarization study of this comet by Astronomy and Astrophysics Division.

Pulsar PSR 0950+08 was observed almost daily with the Rajkot RadioTelescope for last one year. Large fluctuations in the intensity levels of individual giant pulses and in their occurrence rate per unit interval of time are seen during a single day's observations, as well as from day-to-day basis.

The division has made significant contributions towards development of instruments this year. A fibre linked astronomical grating spectrograph has become operational. Near IR Imaging Fabry-Perot Spectrometer (NIFS) between 2-2.5 micron region, coupled with NICMOS-3 detector, is also operational. For simultaneous imaging in optical and near IR spectral region a two channel hybrid camera combining CCD Camera and IR Camera (NICMOS) has been developed. This instrument is being tested on the telescope.

At the Udaipur Solar Observatory main activities continued to be helioseismology using GONG data and the efforts to develop Solar X-ray spectrometer (SOXS) for soft X-rays . Study of Gong data has shown that the properties of acoustic waves, power and frequency of predominant 5-min oscillations depend on magnetic field configuration during their propagation inside sunspots. A unique observing plan was undertaken at Sacramento Peak Observatory, NSO, USA to obtain very high spatial resolution observations of active region to understand the photosphere - chromosphere connection and the role of small scale magnetic fields in the evolution of large scale magnetic field and its variation on the Sun. Another important finding is the detection of two stages of energy release in a solar flare in association with Coronal Mass Ejection on 12 May 1997 as a consequence of collision of two opposite polarities. This study was based on the analysis of SOHO data and also the ground based data in visual region. At USO Video - Magnetograph using Fabri - Perot etalon was developed and is being used to study the evolution of magnetic and velocity fields.

Theoretical Physics

The Division studied a number of problems in atomic and molecular physics, gravitational physics, high energy physics, nuclear physics and plasma physics. Some important results that have been obtained this year are summarised below.

Within the framework of general relativity, models of pulsars, which include the effects arising from rotations and strong magnetic fields, are discussed by using different equations of state. In another work in the Einstein and higher order active gravity, an investigation of photon propagation has shown that Riemann and Ricci curvature couplings lead to a polarization dependent deviation of the photon trajectories from the null geodesics. The curvature corrections give rise to an effective mass of the photons, which keep their velocity sub-luminal i.e., less than the speed of light .

In atomic and molecular physics, a quantum formula of the form factor for transitions between parabolic states is derived in terms of the Jacobi polynomials. This formula leads to the expression of the form factor between parabolic Rydberg states in terms of the Bessel functions, which allows to test the validity of quasi-classical formulas derived earlier in terms of the Airy functions.

In high energy physics, the most important event of the last year was the experimental observations confirming the existence of the neutrino oscillations. The high energy physics group used different ways within the framework of grand unified theories to analyze these experimental observations. It is found that the neutrino masses and generation of baryon asymmetry can be coherently understood within these theories.

In plasma physics, a study of wave propagation and instability excitation in non-ideal dusty plasma was carried out. A new kind of drift-wave as well as Kelvin-Helmholtz instability driven by the dust temperature gradient is found.

In a study of the structure of the nuclei near proton drip line, a O(36) symmetry limit of the IBM model is analyzed and the spectra of both N=Z even-even as well as odd-odd nuclei are investigated.

Nonlinear Dynamics and Computational Physics

The classical dynamics of a particle confined in a one dimensional infinite square well and subjected to a time periodic pulsed electromagnetic field is being studied. This system displays a variety of dynamics which essentially depends on competing length scales in the problem. Some work on the quantum dynamics of this system is underway and preliminary results reveal novel classical-quantum correspondence, in the appropriate semi-classical limit. A method which dynamically minimizes synchronization errror of a time series of a multiparameter chaotic system has been developed to estimate the parameters of the system. The physical characteristics of supergranules on the solar surface have been determined by carrying out wavelet decomposition of dopplergrams obtained from the Gong Experiment.

Laser Physics and Quantum Optics

The research output of this division covers both theoretical and experimental activities in a broad range of

topics on nonlinear and quantum optics with major emphasis on beam propagation, sub-wavelength near-field optics, cavity QED, quantum interference, coherence and wavepacket dynamics.

We show that the tendency of a laser beam to break into a filamentary structure in passing through nonlinear optical medium can be suppressed by proper tailoring of the vacuum field that interacts with the laser beam. In a numerical study of Gaussian beam propagation through a saturable nonlinear medium, we also show how the interplay between the input phase structure and the phase imparted by the nonlinear medium gives rise to different types of optical patterns, including optical vortices. Optical vortices are singularities in the electric field and have many potential applications. Using a computer generated hologram, we were successful in converting the Hermite Gaussian beam of a He-Ne laser into a Laguerre Gaussian beam that contains an optical vortex. We also present the theory of splitting and regeneration of an arbitrary input field inside a multi-mode rectangular waveguide. Our analytical results will be quite useful in the context of establishing design criteria for a variety of waveguide-based optical devices.

The quantum mechanical analogue of beam regeneration and splitting is the phenomena of revival and fractional revival or cat formation. These phenomena are rather generic and occur in a wide range of quantum systems. We show how the initial momentum of a particle in an infinite square well potential affects its wavepacket dynamics. We also show how coherent states of various symmetry groups evolve under a generic two-mode nonlinear Hamiltonian. It is found that all these states undergo revival and in certain cases, form Schrödinger cat - like states although the details of evolution are different for each group. Schrödinger cats have many non-classical properties and are known to be extremely sensitive to environmental interactions. We address the important question of how these states approach classicality by means of a suitably controlled environment.

States can not only be superposed but also entangled. Entanglement is the centerpiece of current developments in quantum teleportation, information theory, quantum computing and cryptography. The subject of state reconstruction also has been a major field of study in recent times. We show how a cavity can be used to reconstruct a two-mode entangled state by using the interaction of a V-configuration three-level atom and by driving the cavity field.

The vacuum of the electromagnetic field is known to give rise to several types of very interesting coherence effects. The condition for the existence of vacuum-induced coherence (VIC) between two closely lying levels of a multi-level atom is rarely met in atomic systems. However, we report that it is possible to bypass this condition by placing the atom, having orthogonal dipoles, inside a cavity whose polarization modes are selected *a priori*. We also suggest how VIC can be probed in both V- and Λ- configuration three level atoms. We show how cross talk among transitions can lead to significant gain.

Conventional approach for the reconstruction of a scattering object by studying the scattered light does not allow resolution smaller than the wavelength of light. We develop a theoretical framework in which we use radiation from an excited dipole placed near the scattering object as the probe and include evanescent waves both in the incident and in scattered fields. In this way, we show that it is possible to obtain sub-wavelength resolution.

Finally, the Z-scan technique has been used to investigate the self-focussing and optical limiting in the photo-refractive BSO crystal. The results are very promising for the eventual observation of spatial solitons that will have important applications in optical switching and routing.

Planetary Atmospheres and Aeronomy

The research activities of the Planetary Atmospheres and Aeronomy Division include the investigations of a wide variety of physical and chemical processes that occur in the atmospheres of the earth, planets and comets. Some of these investigations are carried out using balloon and rocket-borne payloads where as some other programmes are accomplished by performing experiments on ocean cruise. The research work also includes the remote sensing of atmospheres by ground-based

radio and optical techniques, laboratory experiments and atmospheric modelling and numerical simulation studies. The three broad classifications are physics of the middle and upper atmospheres and laboratory astrophysics.

The middle atmospheric research activities are mainly centered around the Indian Ocean Experiment (INDOEX), the ISRO-Geosphere-Biosphere Programme and the ground based measurements of column density of Iodine Oxide and ozone. The highlight of the INDOEX is the Intensive Field Phase campaign held during January to March 1999. Field measurements of radiatively and chemically active constituents such as aerosols, ozone, methane and oxides of nitrogen, made in ship cruises over the Indian Ocean reveal the importance of the inter-tropical convergence zone (ITCZ) in controlling the mixing of continental polluted air with the pristine marine air. Independent measurements of aerosol size distribution and the aerosol spectral optical depth reveal that it is the sub-micron size particles, produced mainly from gas-to-particle conversion mechanism, which are transported to long distances over the ocean surface and are responsible for the observed latitudinal variation in the aerosol radiative forcing. Under the Geosphere- Biosphere Programme, a high altitude balloon carrying the cryogenic air sampler was flown from the National Balloon Launch facility, Hyderabad in April 1998. Altitude distributions of various chemically active trace gases such as CH_4, CO, SF_6, N_2O and CFC's are measured. Comparison of the results obtained with earlier data reveal that, SF_6 shows the highest annual growth rate of about 8% per year while CH_4 and N_2O do not show up any appreciable increase. Another interesting observation is that the annual growth rates of CFC-11 and -12 have started to show a decline as compared to those obtained in 1994. A two dimensional photochemical transport model, developed at the Max Plank Institute of Chemistry, Mainz is successfully installed at PRL and the simulated model results are being used to describe the measured altitude variations in the trace gases' profiles. The Nd:YAG backscatter lidar at Mount Abu is now being operated in the Rayleigh, Mie and Raman scattering mode of studying the vertical profiles of neutral density, temperature and aerosols. Aerosol backscattering measurements from the stratospheric altitude region reveal that the stratosphere is void of any volcanic aerosol layer and represent a volcanically quiescent period.

Measurement of column density for iodine oxide and ozone were also part of the middle atmosphere programme during the year. Iodine oxide was measured at Ahmedabad using the ground based solar absorption technique. The preliminary results show that the slant column density of this molecule is of the order of 10^{14} cm^{-2}. Ozone observations were carried out during the solar eclipse (October, 1995) by various research groups at different places in India. Variations of ozone observed during this period could not be explained by presently known conventional photochemical and dynamical processes.

The upper atmospheric research activities include simultaneous measurements of electron density and electric field fluctuations, I-STEP campaign, optical aeronomy programme and radio sounding of the ionosphere. Through the in-situ simultaneous measurement of electron density and electric field fluctuations, it has been possible to confirm the validity of the image striation theory in the F-region valley and present an evidence of a sheared flow of vertical current in 175-305 km region. During the I-STEP campaign, simultaneous observations of equatorial spread-F (ESF) irregularities by VHF (MST) and HF radars have revealed the dispersive nature in the Doppler velocities. An unique ESF structure similar to the one observed by the MST radar could be explained qualitatively by invoking the interaction between two long wavelength modes in the initial electron density perturbation. This work also revealed that the long wavelength mode developed into bottomside structure where as the second mode developed into multiple plumes. In the optical aeronomy programme, short term scale variabilities in 630 nm thermospheric airglow intensities have been observed indicating the passage of gravity waves. Further, the daytime mesopause rotational temperature from equatorial latitude has been found to exhibit oscillatory features. The radio sounding activity being carried out over Ahmedabad for the last 42 years indicated significant trends in ionosphere after removing the seasonal and solar cycle effects. Lowering of the F_2-layer peak and decrease in the critical frequency of F_2-layer have been detected. The results are consistent with the predictions

made on the basis of cooling of thermosphere due to increase in trace gases. Radio soundings also detected the impact of the Leonid shower event in November, 1998 with increased sporadic-E layer formation coinciding with the peak in meteor rate counts. In the planetary and cometary physics research programme, the activity includes the study of dynamics of the Martian ionosphere, field-aligned current and parallel electric field between the magnetosphere and ionosphere of Mars and the possible search for a mechanism for 193.1 nm OI emission in the cometary comae.

In another major programme of the Division, radiative life time measurements for NO_2 were carried out at excitation photon wavelengths 390-41Ɛ nm using the excimer laser pumped tunable dye laser. The study revealed the existence of three groups of life times. Also, the self-quenching rate constants and zero-pressure life times for NO_2 have been obtained in the three spectral regions 465-490 nm, 423-462 nm and 399-416 nm.

Earth Sciences and Solar System Studies

The Oceanography and Climate Studies and the Solar System and Geochronology constitute two areas of the Earth Sciences Division. The theme of research continues to be application of radio isotope and stable isotope techniques in delineating a variety of Earth and Solar System processes. Particular emphasis was on developing a new geochronological technique and integrating the heat source of meteorite parent bodies. In addition,the division continued to pursue programs on palaeoclimate, ocean circulation, evolution of Indian Lithosphere and Catastrophic events in the Earth's history.

^{187}Re-^{187}Os isotope pair has been successfully used to determine the chronology of black shales from the Lower Tal formation of the lesser Himalaya. These samples, collected a few meters above the Krol-Tal boundary (Pc-C boundary), yield an isochron age of 535±11 Ma consistent with that reported for Pc-C boundary for several other locations around the world. Further, the high radiogenic $^{187}Os/^{188}Os$ in black shales for the inner and outer belts of the lesser Himalaya suggest that their weathering would be an important contributor to the Osmium isotope evolution of the oceans since the cenozoic,

The half life of ^{32}Si has been determined, based on its measurements in a varved sediment core from a lake in Kassjon, North Sweden. The half life is 178±10 years, in agreement with the recent value 172±4 based on direct decay of artificially produced ^{32}Si.

Isotope studies in soil samples from Siwalik hills in Himachal Pradesh reveal that the Monsoon was comparatively intense 4 Ma ago. This result is in agreement with upwelling records from the Arabian Sea. The intensification could have been caused by enhanced uplift of the Himalayas at that time.

The discovery of the now-extinct short-lived nuclide ^{26}Al in the differentiated meteorite Piplia Kalan, reported last year, has been confirmed by additional studies of Al-Mg isotope systematics in individual plagioclase grains using the ion microprobe and bulk plagioclase separates using a thermal ionization mass spectrometer. These results strongly suggest ^{26}Al as the heat source responsible for early melting of the parent body of the Piplia Kalan eucrite and, by inference, parent bodies of other differentiated meteorites.

A model to explain the absence of short-lived nuclides in some of the first solar system solids has been proposed. This envisages formation of these phases near the central region of the collapsing protostar cloud which took place prior to the injection of short-lived nuclides from a nearby stellar source.

A simultaneous study of Ar and N isotopic compositions in several types of mantle derived samples has revealed the presence of a recycled nitrogen component in the mantle of the Earth. The nitrogen isotopic compositions suggest that this component is introduced into the mantle through the subduction of ocean sediments.

The Ar-Ar age for the Sylhet Traps in Eastern India indicates that they are coeval with the Rajmahal Traps located ~ 700 km away to the west and further suggests that these two together may comprise a large igneous province in this region that formed about 117 million years ago.

Research Facilities

Major Equipments

Infrared Telescope at Mt. Abu with back-end instruments like Infrared Camera (NICMOS.3);1Kx1K Pixel Thinned Back Illuminated CCD Camera; Polarimeter both optical and IR; Imaging Fabry-Perot Spectrometer and Infrared Fast Photometer

Solar Telescopes, Video Magnetograph and Dopplergraph Telescope at USO

Radio Telescope at Rajkot

Lidar

Gas Chromatographs

Dobson Spectrophotometer

Digital Ionosonde

Day-Glow Photometer

Multiwavelength Daytime Photometer

Scanning Fabry-Perot Interferometer

Doppler Imaging Spectrometer

All Sky Imaging Camera

UV Photoelectron Spectrometer

Excimer Laser

Ion Probe

Radiation Detectors

Luminescence Dating Systems

Atomic Absorption Spectrophotometer

Ion Chromatograph

CN Analyser

Spinner Magnetometer

Leitz Microscope with accessories

Inductively Coupled Plasma Emission Spectrophotometer (ICP-AES)

Stable Isotope Mass Spectrometer

Solid Source Mass Spectrometer (Rb-Sr & NTIMS)

Noble Gas Mass Spectrometer

Ar-Ar Mass Spectrometer

Nuclear Track Laboratory and X-ray Diffractometer

Radiocarbon Laboratory

New Facilities

The Earth Science and Solar System Division acquired a state of the art stable isotope mass spectrometer and associated automated gas extraction systems to analyse isotopic ratios of hydorgen, carbon, nitrogen, oxygen in natural materials. The main machine, carbonate system, water equilibration system and external sample manifold have been installed. Later, the system passed through a serious test when the concerned scientists participated in an international effort organized by the International Atomic Energy Agency (IAEA) to prepare three new water standards as Isotopic References for $^{18}O/^{16}O$ and D/H ratio measurements. Both oxygen and hydrogen isotopic ratios were measured with high precision (based on a total of about 100 measurements of OH-1, OH-2 and OH-3 water standards distributed by IAEA) using this system.

The Rare Gas Laboratory acquired a laser heating system for release of trapped gases from microscopic spots of single mineral grains. This will be coupled by a metal vacuum extraction system to the existing Noble Gas Mass Spectrometer for measurements of isotopic ratios of noble gases to infer about their origin.

Computer

The Computer Centre at PRL began with the first generation IBM1620 machine in the early sixties. It has today a work-station cluster consisting of five IBM RS6000/580 machines and HP9000/735 machine connected on a high speed fibre optic network. In addition, there are several 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.1.1)

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.1.2)

PRL also offers training and apprentice programmes in computers, electronics, library science, engineering and administrative services (Fig.1.3)

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. Some of our scientists have also edited books.

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 research output during the reporting year are shown in Fig.1.4.

Books/Journals Edited

1. **V. B. Sheorey,** Nonlinear Dynamics and Computational Physics, Narosa Publishing House: New Delhi 1999.
2. **B.L.K. Somayajulu,** Ocean Science : Trends and Future Directions, Indian National Science Academy, New Delhi, 1999.
3. **A. Ambastha**, Solar Physics in India during Next Solar Maximum and Beyond, Bull. Astron. Soc. India, **26**, 1998.
4. H. Faure, K. Heine and **A. K. Singhvi**, Desert Margin Changes in Africa:Palaeoecology of Africa, **25,** 1998.

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. IVth SERC School on Upper Atmosphere, April 6-29, 1998 (Convener: R. Sridharan)
2. First Post Graduate Course in Space Science of the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTE-AP), affiliated to the United Nations, June-November, 1998 (Convener: H.S.S. Sinha)
3. 32nd COSPAR Scientific Assembly, Symposium on Antarctic and Arctic Middle Atmospheres : Their Similarities and Differences, July 12-19, 1998 (Convener: D.K. Chakrabarty)
4. 32nd COSPAR Scientific Assembly, Symposium on Middle Atmosphere and Lower Thermosphere Eletrodynamics, July 12-19, 1998 (Convener: S.P. Gupta)
5. Workshop on High Energy Astrophysical Plasma, December 7-12, 1998 (Convener: A.C. Das)
6. Discussion Meeting on Recent Developments in Neutrino Physics, held at PRL, February 2-4, 1999 (Conveners: A.S. Joshipura and S.D. Rindani)

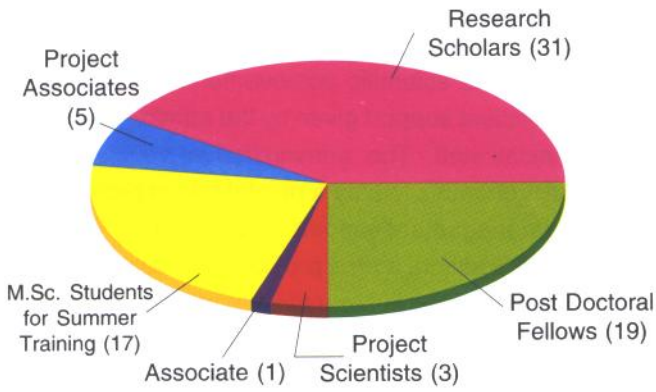


Fig. 1.1 Doctoral, Post Doctoral and Other Research Programmes

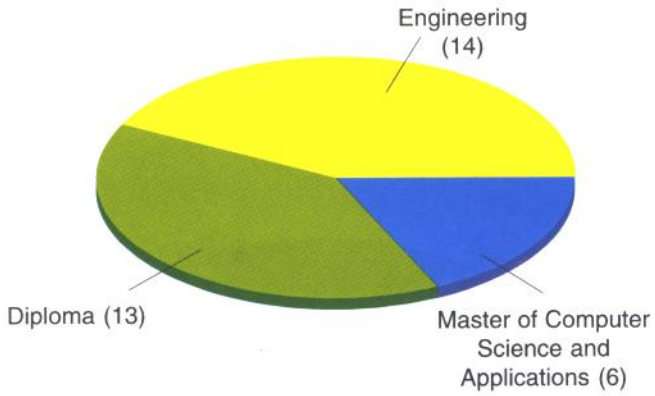


Fig. 1.2 Technical Projects for Engineering and Diploma Students

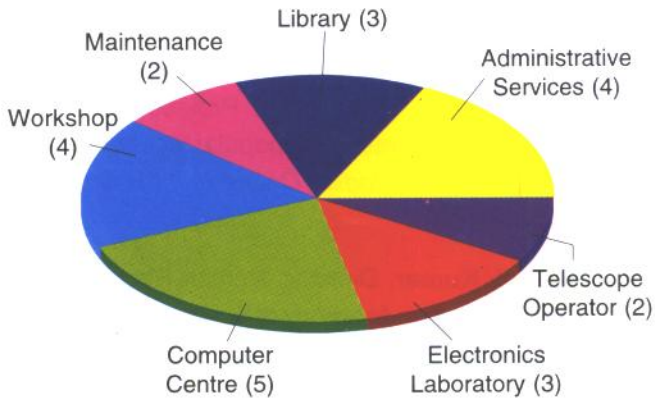


Fig. 1.3. Apprentice Programme at PRL

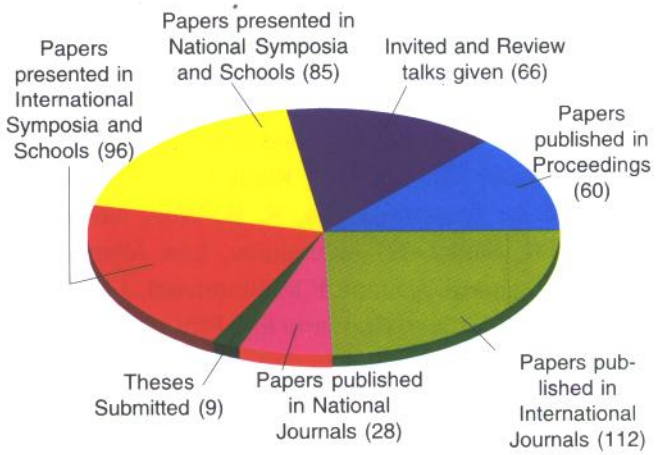


Fig. 1.4 Scientific Output of PRL

7. Meeting on Current Trends in Plasma Physics, February 9-10, 1999 (Convener: D.P. Dewangan)

8. SERC School on Atoms and Molecules in Intense Fields, February 15- March 7, 1999 (Conveners: V. Kumar and V. B. Sheorey)

Distinguished Visitors at PRL

Prof. Gordon G. Shepherd, Distinguished Research Professor, York University, Canada visited PRL as the twenty first **Vikram A. Sarabhai Professor**. During his visit he gave few lectures in UN school and a colloquium on *The Influence of Dynamics on Lower Thermospheric Atomic Oxygen Concentrations.*

Prof. M. R. Kundu from University of Maryland visited PRL as the twenty second **Vikram A. Sarabhai Professor**. During his visit he gave five lectures and a popular lecture on *Storms on the Sun and Space Weather.*

Prof. Oriol Bohigas from Orsay, France visited PRL as the twenty third **Vikram A. Sarabhai Professor**. During his visit he gave four lectures and a colloquium on *Quantum Chaos and the Unreasonable Effectiveness of Mathematics in the Natural Sciences.*

On the occasion of the completion of fifty years of our laboratory on 1997, the Council of Management has established the **K. R. Ramanathan Professorship** to honour Prof. K. R. Ramanathan the Founder Director of the Physical Research Laboratory. **Prof. V. Ramanathan** Director, Centre for Atmospheric Sciences and Centre for

Clouds, Chemistry and Climate, Scripps Institute of Oceanography, University of California, San Diego, USA visited PRL as the first K. R. Ramanathan Professor. During his visit he gave five lectures and a popular lecture on *Global Warming : Role of the Indian Ocean and the Sub-Continent.*

Prof. N. Kumar, Director, Raman Research Institute; President, Indian Academy of Sciences delivered the thirteenth **Prof. K.R. Ramanathan Memorial Lecture** entitled *Waving through Randomness at Maximum Entropy.*

Prof. Madhav Gadgil, Professor,Centre for Ecological Sciences, IISc, Bangalore delivered the fourteenth **Prof. K.R. Ramanathan Memorial Lecture** entitled *Western Ghats : A Lifescape.*

A number of distinguished visitors visited PRL. They are Profs. S. P. Perov, Klaus Legner, James T. Teller, N. C. Wickramsinghe, K. B. Wolf, Nakamura, Richard M. Muller, N. Akhmediev, Les Allen, Philip Morrison, Robert J. Wasson, K.M. Storetvedt, J. H. Eberly, Jan Olof Stenflo, Juan Roederer and Prof. Julius Sykora. A Chinese delegate including distinguished Chinese astronomers, Profs. Huang Keliang, Xiao-Qing Li, Qiu-he Peng, Qui Yuhai and Dr. Qirong Yuan visited the laboratory. The visitors had extensive interactions with PRL scientists. Some of them also delivered seminars and public lectures.

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 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 Figures 1.5 and 1.6.

Miscellaneous

Physical Research Laboratory honoured six distinguished scientists at a glittering investiture function on the occasion of the **Vikram Jayanti**. **Dr. S. Varadarajan**, President, Indian National Science Academy graced the celebrations and gave away the Hari Om Ashram Prerit Vikram Sarabhai Research Awards and the PRL Award.

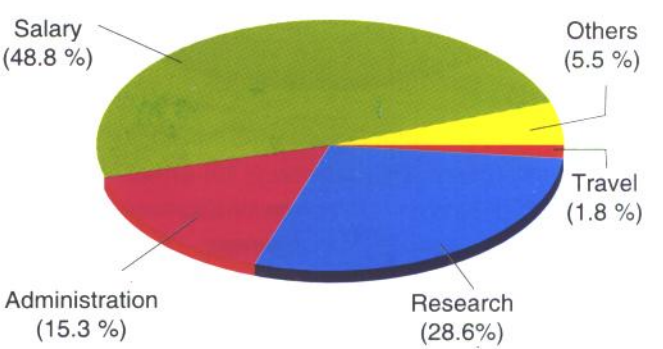


Fig. 1.5 Budget of PRL

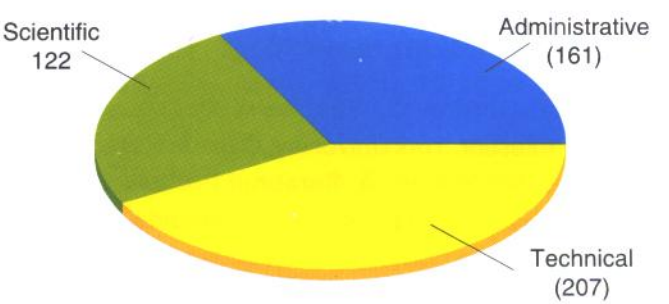


Fig. 1.6 Staff Structure of PRL

Five distinguished scientists received the Hari Om Awards and one received the PRL Award. 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 this year 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: **Ashok Jhunjhunwala** (IIT, Madras) received the award for Electronics, Informatics, Telematics and Automation; **A. R. Rao** (TIFR, Mumbai) and **S. V. S. Murty** (PRL) for Space Sciences; **Ramesh P. Singh** (IIT, Kanpur) for Space Applications; **P. P. Kanjilal** (IIT, Kharagpur) for Systems Analysis or Management. The recipient of the **PRL Award** is **K. Krishna Moorthy** of Space Physics Laboratory of Vikram Sarabhai Space Centre (VSSC), Thiruvanantapuram.

The **National Science Day** was organised on February 27, 1999 at the Physical Research Laboratory in association with the Indian Physics Association (IPA) and Indian National Science Academy (INSA), Ahmedabad Chapter. Science Quiz, both written and oral, popular science lectures and video shows formed part of the programme. The science quiz was open to students of stds. IX and X from schools all over Gujarat. One hundred and thirty two students participated in the written science quiz. To foster scientific temperament, the Indian Physics Association and the Indian National Science Academy, Ahmedabad Chapter has provided a year's subscription of a popular science magazine in English and Hindi to all the participants. The magazine subscription was sponsored by the State Bank of India, Gujarat University Branch; Institute of Plasma Research, Gandhinagar and Shri Arvind M. Kamdar, Bharat Line, Mumbai. In addition, Physical Research Laboratory presented microscopes to top eighteen students from the written science quiz and popular science books to the three best teams in oral quiz. IPA Ahmedabad Chapter also presented cash awards to three best students for individual performance in the oral quiz.

Starting from last year, PRL has instituted five **PRL Scholarships** from the Aruna Lal Endowment Fund established by Prof. D . Lal, Honorary Fellow and former Director, PRL. Five students were selected on the basis of their performance in Science Quiz, both written and oral, and personal interview, held to judge the student's scientific aptitude and motivation for doing science. PRL also continued the scholarships to the five recipients of 1998 PRL Scholarships for their excellent performance in science and maths in their schools. All the ten students were awarded Rs. 3000/- per year.

As a part of implementation and progressive use of Hindi in PRL, the **Hindi Week** was celebrated at PRL from September 14 - 19, 1998. The highlights of the celebrations included word quiz, essay, elocution, poetry and recitation competitions, including self written poetry and Antakshari. All staff members alongwith their families were invited in some of the programmes to make this celebration attractive. The special attraction of this year's celebrations was lectures of two eminent personalities - one **Prof. Ambashankar Nagar,** Chairman, Gujarat Hindi Sahitya Parishad who gave the inaugural lecture, the other was **Prof. Rama** of Tata Institute of Fundamental Research *(TIFR), Mumbai who gave a very interesting talk on "Panch Ratno Ki Kahani, Meri Jubani, Pani hi Pani".*

The **PRL** was awarded the **first Running Shield for the year 1997-98 by Town Official Language Implementation Committee**, Ahmedabad for its pioneering role in using the different computer softwares in Hindi in various fields and also training and promulgation of the same to the member offices located in Ahmedabad. The shield was given away by the Chief Commissioner of Income Tax Shri S.N.L. Agrawal.

PRL has also participated in **DOS Inter Centre Technical Seminar** held at ISTRAC, Bangalore during 23-24 December, 1998 in which 11 papers were sent. Seven persons participated in this seminar and presented their papers on various topics. Hindi Officer of the laboratory participated in various symposium, seminar and workshops organised by the Space Application Centre, Akashvani, Kribhco, ONGC, NTC, Oriental Insurance Company in Ahmedabad, Bangalore and Surat and gave talks on different topics including Internet ka Network.

Awards and Honours

1. **Prof. U. R. Rao** has been awarded the *D.Sc. (Honoris Causa)* from the Indian School of Mines, Dhanbad.

2. **Prof. G. S. Agarwal** delivered:
   a. the *R.D. Birla Award Lecture* of the Indian Physics Association on April 20, 1998 at BARC, Bombay.
   b. the *Shyamadas Chatterjee Endowment Lecture* of the Indian Physical Society for the year 1998-99 in Calcutta.

3. **Dr. R. Ramesh** has been awarded the prestigious *1998 Shanti Swarup Bhatnagar Prize by the Council of Scientific and Industrial Research,* for his outstanding contribution in the field of Earth, Atmosphere, Ocean and Planetary Sciences.

4. **Dr. S.V.S. Murty** has been awarded the *1997 Hari Om Ashram Prerit Vikram Sarabhai Research Awards* for his outstanding research in the field of Space Sciences.

5. **Dr. A. Lakshminarayan** has been awarded the *1998 Indian National Science Academy (INSA) Medal for Young Scientists* for his outstanding research in the field of Physics.

6. **Dr. R. Rangarajan** has been selected the *Associate of Indian Academy of Sciences* for the year 1998 for his outstanding research in Cosmology and Particle Physics.

7. **Dr. G.Srinivasan** received the *Alfred O. Nier Prize* of The Meteoritical Society for the year 1998.

8. **Dr. Shikha Raizada** has been selected for the *Young Scientist Award of International Union for Radio Science (URSI)* and invited to participate in the URSI Assembly to be held at Toronto, Canada in August 1999.

9. **Prof.J.N.Goswami** became one of the *Associate Editors of Geochemical Journal* published by Geochemical Society of Japan.

10. **Dr. J. S. Ray** received the *PRL Gold Medal for the Best Thesis* for the year 1997 for his thesis entitled Stable and Radio Isotopic Constraints on the Evolution of Mesozoic Carbonatite - Alkaline Complexes of India.

11. **Shri A. Das and Shri A. D. Shukla** has been awarded the *Third Best Paper and Presentation Award* for their paper entitled A rapid NiS bead technique for measurements of picogram concentrations of platinum group elements (PGEs) following neutron activation, at the Nuclear and Radiochemistry Symposium (NUCAR99) at Bhabha Atomic Research Centre, Mumbai held on January 19-22,1999.

12. The paper by **M. G. Yadava and R. Ramesh** on "Late Holocene environmental records from stable isotopes in tropical speleothems" won the *Poster Award Competition for Developing Countries*, conducted by the PAGES Open Science Meeting, International Geosphere Biosphere Programme, London, UK, 20-23 April, 1998.

13. The paper by **A. K. Singhvi, M. S. Rao, A. Bluczsz and C. S. R. Murthy** on "Synthesis of luminescence chronology of loess accumulation episodes and implications for global land-sea correlation" won the *Poster Award Competition for Developing Countries*, conducted by the PAGES Open Science Meeting, International Geosphere Biosphere Programme, London, UK, 20-23 April, 1998.

Papers Published in Journals in 1998-99

Review Papers

Theoretical Physics

Gravitation Physics

1. Mohanty, S. and Sahni, V. "Astroparticle Physics : Working Group Report", Pramana, **51**, 273 - 286 (1998).

High Energy Physics

2. Mohanty, S. "Astrophysical Constraints on Particle Properties", Pramana, **51**, 229 - 237 (1998).

Papers Published

Astronomy and Astrophysics

3. Deshpande M.R., Joshi U.C., Baliyan K.S. and Ganesh S., "Microvariability in Blazars", Astrophys. & Space Sci. **258,** 9-14 (1998).

4. Janardhan P., Bird M K., Edenhofer P., Plettemeier D., Wohlmuth, R., Asmar S W., Patzolt M. and Karl J., "Coronal Velocity Measurements with Ulysses: Multi-link Correlation Studies During Two Superior Conjunctions", Sol. Phys., **184**, 157-173 (1999).

5. Kamath U.S. and Ashok N.M., "Near IR Photometry of the Final Helium Shell Object V4334 Sagittarii", Mon. Not. R. Astron. Soc., **302**, 512-514 (1999).

6. Kamath U.S. and Ashok N.M., "JHK Photometry of Symbiotic Stars", Astron. Astrophys. Suppl. Ser., **135**, 199-202 (1999).

7. Kamath U.S. and Ashok N.M., "Near Infrared Photometry of Nova Cassiopeiae 1995", Astron. Astrophys. Suppl. Ser., **136**, 107-110 (1999).

8. Tej Anandamayee, Chandrasekhar T., Ashok N.M., Ragland Sam, Richichi A. and Stecklum B., "Near Infrared Angular Diameter of Mira Variable R Leonis at 3.36microns and 2.2microns", Astronomical J., **117**, 1857-1863 (1999).

9. Vats Hari Om, Iyer K.N., Oza R.M., Mehta M., Deshpande M.R. and Kojima M., "Solar Wind - Structure and Dynamics", Bull. Astro. Soc. India, **26**, 219-224 (1998).

10. Vats Hari Om, Deshpande M.R., Shah C.R. and Mehta M., "Plasma Disturbances Associated with Solar Burst", Ind. Jou. Radio and Space Phys., **27**, 87-90 (1998).

11. Vats Hari Om, Deshpande M.R., Shah C.R. and Mehta Mehul, "Rotational Modulation of Microwave Solar Flux", Solar Phys. **118**, 351-362 (1998).

12. Vats Hari Om, Deshpande M.R., Mehta M., Shah C.R. and Shah K.J., "Correlation and Fractal Analysis for Solar Coronal Rotation", Moon, Earth & Planets, **76**, 141-146 (1998).

13. Vats Hari Om, Singal Ashok K., Deshpande M.R., Iyer K.N., Oza Rupal, Shah Chhaya R. and Doshi S., "A Possible Detection of Radio Pulses from Geminga at 103 MHz", Mon. Not. R. Astron. Soc., **303**, L65-L67 (1999).

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71. "Study of solar wind transients using IPS." at the *Solar Wind 9*, Nantucket Island, **Massachusetts, USA**, October 5-9, 1998, by S. Ananthakrishnan, M. Kojima, M. Tokamaru, S. Balasubramanian, P. Janardhan, P.K. Manoharan and M. Dryer.

72. "Coronal mass ejections and their signatures in the interplanetary scintillation observations at 103 MHz", at the *AGU Chapman Conference on Space Based Radio Observations at Long Wavelengths*, **Paris**, October 18-24, 1998, by Hari Om Vats, R. Oza, R. Jain, K.N. Iyer, Som Sharma and M.R. Deshpande.

73. "A high speed near Infrared occultation photometer", at the *International Conference on Optics and Opto-Electronics,* **Dehra Dun**, December 1998, by S. Mondal, T. Chandrasekhar, N.M. Ashok and P.K. Kikani.

74. "Angular diameter and mode of pulsation of mira variable R leonis at 3.36 μm from lunar occultations", at the *XIX Astronomical Society of India Meeting, RRI*, Bangalore, February 1-4, 1999, by Anandamayee Tej, T. Chandrasekhar and N.M. Ashok.

75. "Jets and outflows from young stars", at the *Meeting of the XIX Astronomical Society of India*, RRI, Bangalore, February 1-4, 1999, by M.S. Nandakumar and B.G. Anandarao.

76. "Star formation studies using molecular hydrogen emission lines", at the meeting of the *XIX Astronomical Society of India*, RRI, Bangalore, February 1-4, 1999, by B.G. Anandarao and M.S. Nandakumar.

77. "FLAGS - a fibre linked astronomical grating spectrograph", at the meeting of *XIX Astronomical Society of India*, RRI, Bangalore, February 1-4, 1999, by D.P.K. Banerjee, S.D. Rawat, F.M. Pathan and B.G. Anandarao.

78. "Studies of classical novae and related objects" at the *XIX Meeting of Astronomical Society of India*, RRI, Bangalore, February 1-4, 1999, by U.S. Kamath **(Thesis presentation).**

79. "Simultaneous imaging in optical and near IR bands", at the *XIX Meeting of the Astronomical Society of India*, RRI, Bangalore, February 1-4, 1999, by N.M. Vadher, A.B. Shah, A.J. Shroff and U.C. Joshi .

80. "Instrumentation of solar X-ray spectrometer low energy detector (SLD)- proposed payload onboard Indian satellite" at the *XIX Meeting of the Astronomical Society of India*, RRI, Bangalore, February 1-4, 1999, by N.M. Vadher, A.B. Shah, R. Jain, Hari Om Vats, M.R. Deshpande, S. Seetha, M.R. Sharma and C.N. Umapthy.

81. "Statistics of occurrence of giant pulses from PSR0950+08", at the *XIX Meeting of Astronomical Society of India*, RRI, Bangalore, February 1-4, 1999, by Ashok K. Singal, Hari Om Vats and M.R. Deshpande.

82. "Study of solar coronal rotation", at the *XIX Meeting of the Astronomical Society of India,* RRI, Bangalore, February 1-4, 1999, by Hari Om Vats, M.R. Deshpande, C.R. Shah and M. Mehta.

83. "Photo-ionization cross sections for the Fe XVII ion", at the *XIX Astronomical Society of India Meeting*, February 1-4, 1999, RRI, Bangalore, by K.S. Baliyan and U.C. Joshi.

84. "Near infrared spectroscopy of nova sagittarii 1998", at the *XIX Astronomical Society of India Meeting*, February 1-4, 1999, RRI, Bangalore, by N.M. Ashok and T. Chandrasekhar.

85. "JHK photometry of some young clusters", at the *XIX Astronomical Society of India Meeting*, Feb. 1-4, 1999, RRI, Bangalore, by U.C. Joshi, K.S. Baliyan and C.R. Shah.

86. "Study of variability in BL Lac objects, Mrk 421 and Mrk 501", at the *XIX Astronomical Society of India Meeting*, February 1-4, 1999, RRI, Bangalore, by U.C. Joshi, K.S. Baliyan, S. Ganesh, M.R. Deshpande, S. Bhattacharya, C.L. Kaul, R.K. Kaul and C.L. Bhat.

87. "Evidence for sub-photospheric origin of coronal electric currents in NOAA AR No. 8038 during 09 - 13 May, 1997", at *Chapman Conference on Magnetic Helicity in Space and Laboratory Plasmas* held at National Center for Atmospheric Research, High Altitude Observatory, **Boulder, USA**, during 28-31 July, 1998 by Rajmal Jain.

88. "H-alpha intensity oscillations in solar flares", at Chapman Conference on *Magnetic Helicity in Space and Laboratory Plasmas* held at National Center for Atmospheric Research, High Altitude Observatory, **Boulder, USA**, during 28-31 July, 1998 by Rajmal Jain.

89. "Solar activity in NOAA Active region No. 8038 during 08-13 May, 1997", at *19th NSO/SP Summer Workshop on High Resolution Solar Physics: Theory, Observations and Techniques*, held at Sunspot, **New Mexico, USA** during September, 28 -October 02, 1998 by Rajmal Jain.

90. "High spatial and temporal resolution observations to probe the oscillations in solar flares", at *19th NSO/SP*

Summer Workshop on High Resolution Solar Physics: Theory, Observations and Techniques, held at Sunspot, **New Mexico, USA** during September, 28 - October 02, 1998 by Rajmal Jain.

91. "Science from solar X-ray spectrometer (SOXS) - proposed payload onboard Indian satellite", at *XIXth Annual Meeting of Astronomical Society of India*, held at RRI, Bangalore, during 01-04 February, 1999 by Rajmal Jain.

92. "GONG p-mode frequency changes with solar activity", at *XIXth Annual Meeting of Astronomical Society of India*, held at RRI, Bangalore, February 1-4, 1999, by A. Bhatnagar, Kiran Jain and S.C. Tripathy.

93. "A relation between the frequency shift and changes in activity indices", held at *XIXth Annual Meeting of Astronomical Society of India*, RRI, Bangalore, February 1-4, 1999, by Kiran Jain, S.C. Tripathy, Brajesh Kumar and A. Bhatnagar.

94. "On the power and frequency of p-modes in sunspots", held at *XIXth Annual Meeting of Astronomical Society of India*, RRI Bangalore, February 1-4, 1999, by Brajesh Kumar, R. Jain, S.C. Tripathy and M.R. Deshpande.

95. "P-mode frequency changes around solar minimum", in *Workshop on Helioseismology at Moderate and High Spherical Harmonic Degree*, **Tucson (USA)**, March 22-24, 1999, by A. Bhatnagar, Kiran Jain and S.C. Tripathy

96. "A relationship between the frequency shift and activity indices", in *Workshop on Helioseismology at Moderate and High Spherical Harmonic Degree*, **Tucson (USA)**, March 22-24, 1999, by Kiran Jain, S.C. Tripathy, Brajesh Kumar and A. Bhatnagar

97. "P-mode oscillations in and around a sunspot", in *Workshop on Helioseismology at Moderate and High Spherical Harmonic Degree*,**Tucson (USA)**, March 22-24, 1999, by Brajesh Kumar, S.C. Tripathy, R. Jain and M.R. Deshpande.

Theoretical Physics

Gravitation Physics

98. "Rotating compact objects with magnetic fields", *at the 19th Texas Conference on Relativistic Astrophysics*, **Paris**, 13-18 December,1998, by A. R. Prasanna et al.

99. "Propagation of gravitational waves through a dispersive medium", *at the 19th Texas Conference on Relativistic Astrophysics*, **Paris**, 13-18 December, 1998 by A. R. Prasanna.

High Energy Physics

100. "Leptogenesis via heavy majorana neutrinos", *XIII DAE Symposium on High Energy Physics*, Punjab University, Chandigarh, December 26-30, 1998, by H. Mishra, and R. Rangarajan.

101. "Understanding vacuum solutions of neutrino anomalies in a gauge model", at the *XIII DAE Symposium on High Energy Physics*, Chandigarh, December 26-30, 1998 by S. D. Rindani.

102. "Vacuum solutions of neutrino anomalies through softly broken U(1) symmetry", at the *Workshop on Future of Neutrino Physics*, Institute for Cosmic Ray Research, University of Tokyo, Tokyo, **Japan**, March 4-5, 1999, by S. D. Rindani.

Plasma Physics

103. " Field aligned current and particle acceleration near Io", in *Proc. VII International Plasma Astrophysics and Space Physics Conference*, Max Planck Institut fur Aeronomie, **Germany,** 1999, by A. C. Das and W-H Ip.

Non Linear Dynamics and Computational Physics

104. "Second PN gravitational wave polarisations for inspiralling binaries in elliptical orbits", in the *34th Recontres de Moriond Conference on Gravitational Waves and Experimental Gravity*, **France**, January 23-30, 1999, by A. Gopakumar and Bala R. Iyer.

105. "Simulation of seasonal climates and sensitivity sutdies with PRL-GCM in global change studies", *at the Proc. Second Workshop on ISRO-GBP Results*, Bangalore, by S. V. Kasture, Biju Thomas and V. Satyan.

Laser Physics and Quantum Optics

106. "Holographic storage of correlation functions of partially coherent fields", at the *Annual Meeting of the Optical Society of America 1998*, Baltimore, **Maryland, USA**, October 4-9, 1998, by E. Wolf, Tomohiro Shirai and Girish Agarwal.

107. "Theory of beam splitting in a multi-mode rectangular waveguide", at the *International Conference on Optics and Opto-electronics*, **Dehradun, India**, 9-12 December 1998, by J. Banerji, A. R. Davies and R. M. Jenkins.

108. "Quantum coherences from polarization preselection of cavity vacuum", at the *National Laser Symposium*, Kanpur, December 14-16, 1998, by Anil K. Patnaik.

109. "Gain from cross-talk among optical transitions", at the *National Laser Symposium*, Kanpur, December 14-16, 1998, by Sunish Menon.

110. "Wave packet evolution of SU(1,1) coherent states: revival and fractional revival", at the *National Laser Symposium*, Kanpur, December 14-16, 1998, by J. Banerji.

111. "Electro-optic properties of an organic crystal Vanillin", at the *National Laser Symposium*, IIT, Kanpur, December 14 - 16, 1998, by P. Sreeramana Aithal and P. Mohan Rao.

112. "Characterization of organic nonlinear optical crystals of benzoyl glycine", at the *International Conference in Assia (IUMRS - ICA - 98)*, Indian Institute of Science, **Bangalore, India**, October 13 - 16, 1998, by H.S. Nagaraja, U.V. Upadyaya, P.M.Rao, P.Sreeramana Aithal and A.P.Bhat.

113. "Growth and characterization of a new organic nonlinear crystal parahydroxy acetophenone", at the *International Conference in Assia (IUMRS - ICA - 98)*, Indian Institute of Science, **Bangalore, India**, October 13 - 16, 1998, by P. Sreeramana Aithal, and P. Mohan Rao

114. "Electro-optic properties of a new organic nonlinear crystal methyl hydroxy benzoate", at the *International Conference in Assia (IUMRS - ICA - 98)*, Indian Institute of Science, **Bangalore, India**, October 13 - 16, 1998, by P. Sreeramana Aithal, and P. Mohan Rao

115. "Effect of high energy ion irradiation on dielectric and mechanical properties of organic nonlinear crystal parahydroxy acetophenone", at the *International Conference in Assia (IUMRS - ICA - 98)*, Indian Institute of Science, **Bangalore, India**, October 13 - 16, 1998, by P. S. Aithal, P. Mohan Rao and D.K. Avasthi

116. "Possibility of waveguide formation on nonlinear organic crystal methyl hydroxy benzoate using high energy ion implantation", at the *International Conference in Assia (IUMRS - ICA - 98)*, Indian Institute of Science, **Bangalore, India**, October 13 - 16, 1998, by P. Sreeramana Aithal, P. Mohan Rao and D.K. Avasthi.

117. "Modification of microhardness of organic nonlinear crystal para hydroxy acetophenone using swift ion irradiation", at the *International Conference on Swift Heavy Ions in Materials Engineering and Characterization*, Nuclear Science Centre, **New Delhi, India** October 19 - 22, 1998, by P.Sreeramana Aithal, A.P. Bhat, P.Mohan Rao and D.K. Avasthi.

118. "Effect of silver and silicon ions on dielectric properties of pure and doped ADP crystals", at the *International Conference on Swift Heavy Ions in Materials Engineering and Characterization*, Nuclear Science Centre, **New Delhi, India** October 19 - 22, 1998, by A.P. Bhat, P. Sreeramana Aithal, H.S. Nagaraj, P.Mohan Rao and D.K. Avasthi

119. "Ion beam modification of organic solids - prospects in photonics", at the *International Conference on Swift Heavy Ions in Materials Engineering and Characterization*, Nuclear Science Centre, **New Delhi, India** October 19 - 22, 1998, by P.M.Rao, P.Sreeramana Aithal, U.V. Upadyaya, A.P.Bhat and D.K. Avasthi

120. "Comparative study of electro-optic properties of some parahydroxy substituted organic nonlinear crystals", at the *International Conference on Optics and Opto-electronics*, **Dehra Dun, India** December 9 - 12, 1998, by P. Sreeramana Aithal and P.Mohan Rao

121. "Enhancement of second harmonic generation efficiency of some doped KDP crystals", at the *International Conference on Optics and Opto-electronics*, **Dehra Dun, India** December 9 - 12, 1998, by A.P. Bhat, P. Sreeramana Aithal, H.S. Nagaraj and P.Mohan Rao.

Planetary Atmospheres and Aeronomy

122. "Unusual behaviour of electrical parameters in the stratosphere during a thunderstorm day, could it be due to red sprites/blue jets?", at the *32nd Scientific Assembly of COSPAR*, **Nagoya**, Japan, July 12-19, 1998, by D.K. Chakrabarty.

123. "On IRI model of low latitude lower ionosphere" at *32nd Scientific Assembly of COSPAR*, **Nagoya**, Japan, July 12-19, 1998, by D.K. Chakrabarty.

124. "Wind characteristics in the tropical mesopause region during winter", at the *32nd Scientific Assembly of COSPAR*, **Nagoya**, Japan, July 12-19, 1998, by S.R. Das and D.K. Chakrabarty.

125. "Two steam instability in E region over magnetic equator during morning hours", at the *32nd Scientific Assembly of COSPAR*, **Nagoya**, Japan, July 12-19, 1998, by S.P. Gupta.

126. "Solar cycle variation on stratospheric conductivity", at the *32nd Scientific Assembly of COSPAR*, **Nagoya**, Japan, July 12-19, 1998, by S.P. Gupta.

127. "Rocket experiments during Leonid meteor shower activity during November, 1999", at the *13th National Symposium on Plasma Science and Technology, Plasma 98*, Rajkot, October 27-30, 1998, by S.P. Gupta.

128. "Ions distribution in the plasma sheet of Mars",at the *32nd COSPAR Scientific Assembly*, **Nagoya**, Japan, July 12-19, 1998, by S.A. Haider.

129. "Modeling of metastable carbon atoms in comets : implication for Rosetta", *32nd COSPAR Scientific Assembly*, **Nagoya**, Japan, July 12-19, 1998, by S.A. Haider.

130. "In situ study of aerosol characteristics over the Arabian sea and Indian ocean of relevance to correction of satellite remote sensed data", at the *32nd COSPAR Assembly*, July 11-19, 1998, **Nagoya**, Japan, by A. Jayaraman and S. Ramachandran.

131. "Upper tropospheric and stratospheric structure over Mount Abu studied using a backscatter lidar", at the *32nd COSPAR Assembly*, July 11-19, 1998, **Nagoya**, Japan, by A. Jayaraman, Y.B. Acharya and H. Chandra.

132. "Results on direct radiative forcing of aerosols obtained over the tropical Indian ocean", at the *National Workshop on Indian INDOEX Program*, November 16-18, 1998, NPL, New Delhi, by A. Jayaraman.

133. "Ozone and related gases over the tropical Indian ocean", at the *International Symposium on Global Atmospheric Chemistry*, August 19-25, 1998, **Seattle**, USA, by Naja, M. and Shyam Lal.

134. "Variabilities in O_3, NO, CO and CH_4 over the tropical Indian ocean", at the *Indian INDOEX Workshop*, November 1998, New Delhi, by Naja, M. and Shyam Lal.

135. "Evidence of quasi-vertical transport in the tropical stratosphere", at the *First International Workshop on Long-term Changes and Trends in the Atmosphere*, February 16-19, 1999, **Pune**, by P.K. Patra, S. Lal, P.J. Crutzen and C. Bruehl.

136. "Total electron scattering cross sections for carbon monoxide at low electron energies", at the *XII National Conference on Atomic and Molycular Physics*, M.S. Sukhadia University, Udaipur, 29 December 1998-2 January, 1999 by P. Rawat, K.P. Subramanian and Vijay Kumar.

137. "Role of molecular ions in the development of equatorial spread-F irregularities", in the *13th National Symposium on Plasma Science and Technology* held at Saurashtra University, Rajkot, October, 27-30, 1998, by R. Sekar and E.A. Kherani.

138. "The study of NO_2 life times in the excitation wavelength 465-490 nm", in the *XII National Conference on Atomic and Molecular Physics*, M.S. Sukhadia University, Udaipur, December 1998, by V. Sivakumaran, K.P. Subramanian and Vijay Kumar.

139. "Excess ionospheric plasma density due to solar flare of 9 July 1996", at the *XIII National Symposium on Plasma Science and Technology*, Saurashtra university, Rajkot, October 27-30, 1998, by Som Sharma, H. O. Vats, K. N. Iyer, Rupal Oza, H. Chandra and M. R. Deshpande.

140. "Variation of plasma density of sporadic E layer and its association with meteor activity over Ahmedabad", at the

XIII National Symposium on Plasma Science and Technology, Saurashtra university, Rajkot, October 27-30, 1998, by Som Sharma, H. S. S. Sinha, H. Chandra and H. O. Vats.

141. "Long term trends in sulfur hexafluoride", at the *First International Workshop on Long-term Changes and Trends in the Atmosphere*, February 16-19, 1999, **Pune**, by Varun Sheel, Shyam Lal and C. Bruehl.

Earth Sciences and Solar System Studies

142. "A new class of mass independent oxygen isotopic fractionation in photodissociation of carbon dioxide", at the *Final Research Co-ordination Meeting on Isotope-aided Studies of Atmosphsic Carbondioxide*, **Groningen, Netherlands,** 8-11 Setember, 1998 by S. K. Bhattacharya.

143. "Signature of monsoon and Arabian Sea biogeochemistry on trace gases at Cape Rama", at the *Final Research Co-ordination Meeting on Isotope-aided Studies of Atmosphsic Carbondioxide*, **Groningen, Netherlands,** 8-11 Setember, 1998 by S. K. Bhattacharya.

144. "Ascertaining changes in physical and chemical properties of the Arabian sea : Reoccupation of the GEOSECS stations after two decades", at the *2nd Intl. Conf. on Environmental Science*, RRL, **Trivandrum**, Decmber 2-4, 1998, by R. Agnihotri, R. Bhushan, A. Dubey, K. Dutta, S. Karthikeyan, R. Rengarajan and B.L.K. Somayajulu.

145. "Geochronology and geochemistry of Precambrian mafic magmatic rocks of the Western Himalaya petrogenetic and tectonic implications" at the *Ninth International Conference on Geochronology, Cosmochronology and Isotope Geology*, **Beijing**, China, August 20-26, 1998, by Ahmad, T., Mukherjee, P.K. and Trivedi, J.R.

146. "High permian CO_2 levels : Evidence from Satpura palaeosol, Central India", at the *International Conference on Geochronology and Isotope Geology-9, held* at **Beijing**, China, 20-26 August, 1998, by S.K. Bhattacharya, Prosenjit Ghosh, P. Ghosh and S. Roy.

147. "Pressure dependence of isotopic enrichment in ozone : Stratospheric implications", at the *First Annual Environmental Chemistry Meeting, Department of Chemistry and Biochemistry*, UCSD, La Jolla, **California**, 25 April, 1998, by S.K. Bhattacharya, J. Savarino and M.H. Thiemens.

148. "Bomb radiocarbon in the Arabian sea : Estimates of the rates of air-sea CO_2 exchange and upwelling", at the *2nd Intl. Symp. on CO_2 in the Oceans*, Tsukuba, **Japan**, January 18-22, 1999, by R. Bhushan, K. Dutta, B.L.K. Somayajulu and S. Krishnaswami.

149. "Heliospheric behaviour in the past by Titanium-44 measurement in chondrites", at the *61st Meteoritical Societ Meeting*, Dublin, **Ireland**, July 27-31, 1998, by G.Bonino, G.Cini Castagnoli, P.Della Monica, C.Taricco and N.Bhandari.

150. "Cosmogenic radionuclides and tracks in the fresh fall Portals Valley", at the *30th Lunar and Planet. Sci. Conference*, **Houston**, Texas, March 15-19, 1999, by G.Bonino, G. Cini Castagnoli, C.Taricco, N.Bhandari and M.Killgore

151. "A rapid NiS bead technique for measurements of picogram concentrations of platinum group elements (PGEs) following neutron activation", at the *Nuclear and Radiochemistry Symposium*, BARC, Mumbai, January 19-22, 1999, by A. Das and A.D. Shukla.

152. "Analysis of trace metals in natural waters by ICP-AES using an ultrasonic nebulizer", at the *National Symposium on Environmental Geochemistry*, Osmania University, Hyderabad, June 26-27, 1998, by M.H. Dixit and M.M. Sarin.

153. "Ahmedabad city - problems of water supply, hydrological constraints and possible solutions", at the *British Hydrological Society, Int. Symp.*, **Exeter, UK**, July 6-10, 1998, by S.K. Gupta.

154. "Renovation of primary settled waste water using Sabarmati riverbed soil-aquifer system - A pilot study", *National Symp. on Sustainable Groundwater Development and Management*, Anna University, Chennai, November 5-8, 1998 by S.K. Gupta.

155. "Akshaydhara - beyond rainwater harvesting in urban areas : Potential constraints and policy implications", at the *National Conf. on Potential of Water Harvesting: Traditions, Policies and Social Mobilisation*, October 3-5,

New Delhi, 32, 1998, by S. K. Gupta and Mayur Shah., .

156. "Modelling contamination of drinking water supply well in Sabarmati river bed, Ahmedabad city", *National Symposium on Sustainable Groundwater Development and Management*, Anna University, Chennai, November 5-8, 33, 1998, by V. V. S. Gurunada Rao and S. K. Gupta.

157. "Thermoluminescence measurements in various wavelengths: potential for meteorite dating", at the *XXX Lunar and Planet Sci. Congress*, **Houston**, 1999, by A.J.C. Jink, M.R. Krbetschek, T. Trautman, A.K. Singhvi and W. Stolz.

158. "Nitrogen in earth's mantle : Inferences from a comprehensive study of the mantle derived materials", at the *Conference on Origin of the Earth and Moon* held at Monterey, **California**, December 1-3, 1998, by R.K.Mohapatra and S.V.S.Murty.

159. "Cosmogenic records in the Didwana-Rajod meteorite", at the *61st Meteoritical Society Meeting*, Dublin, **Ireland**, July 27-31, 1998, by B.S.Paliwal, V.K.Vaya, A.D.Shukla, S.Chakraborty, K.M.Suthar, M.H.Dixit, P.N.Shukla and N.Bhandari.

160. "Nitrogen and argon in Shergotty", at the *61st Mete oritical Society Meeting*, Dublin, **Ireland,** July 27-31, 1998, by R.K.Mohapatra, R.R.Mahajan and S.V.S.Murty.

161. "Climate reconstruction from the varve deposits at Goting, Chamoli, Garhwal", at the *Symposium on the Quaternary of India*, Nagpur University, Nagpur, 19-21 February, 1999, by R.K. Pant, Navin Juyal, P. Rautela, P.Ghosh, M.G. Yadava, S.K. Bhattacharya , N.K. Saini and S.J. Singode.

162. "Isotopic and trace-element abundances in Murchison hibonites", at the *61st Meteoritical Societ Meeting*, Dublin, **Ireland**, July 27-31, 1998, by S.Sahijpal, A.M.Davis and J.N.Goswami.

163. "Lohawat howardite : Chemical and mineralogical charactiristics and cosmogenic records", at the *61st Meteoritical Societ Meeting*, Dublin, **Ireland**, July 27-31, 1998, by U.K.Singh, M.S.Sisodia, A.D.Shukla, S.Chakraborty, K.M.Suthar, M.H.Dixit, P.N.Shukla and N.Bhandari.

164. "Re-Os systematics in black shales of the lesser Himalaya", at the *Ninth International Conference on Geochronology, Cosmochronology and Isotope Geology*, **Beijing**, China, August 20-26, 1998, by S.K. Singh, J.R. Trivedi and S. Krishnaswami.

165. "Sr Isotopes in the lesser Himalayan carbonates : Implications to $^{87}Sr/^{86}Sr$ of the Ganga-Indus source waters", at the *Ninth International Conference on Geochronology, Cosmochronology and Isotope Geology*, **Beijing**, China, August 20-26, 1998, by S.K. Singh, J.R. Trivedi and S. Krishnaswami.

166. "Re-Os chronology of black shales from the Tal and Shali formations, Lesser Himalaya, India" at the *14th Himalayan Karakoram Tibet Workshop*, University of Tubingen, **Germany**, by S.K.Singh, J.R. Trivedi and S. Krishnaswami.

167. "Stable C and O isotopes in unaltered calcite carbonatites of Amba Dongar, Mundwara and Sarnu-Dandali carbonatite complexes, India", at the *International Conference on Geochronology, Cosmochronology and Isotope Geology*, **Beijing**, China, 20-26 August, 1998, by J. S. Ray and R. Ramesh.

168. "Increased levels of trace metals in groundwaters from an industrial area of Ahmedabad city", at the *ANACON-98 Chemistry in the Next Millennium*, held at Nehru Centre, Mumbai, 17-19 December, 1998, by M.M. Sarin and M. H. Dixit.

169. "^{234}Th scavenging and particle export from the upper Arabian Sea ", at the *International Scientific Symposium on Biogeochemistry of the Arabian Sea: Synthesis and Modelling*, held at **Bangalore**, 18-20 January, 1999 by M.M. Sarin, R. Rengarajan and V.Ramaswamy.

170. "NO_3 and ^{210}Pb distribution in aerosols and their deposition flux to the surface Arabian Sea", at the *International Scientific Symposium on Biogeochemistry of the Arabian Sea: Synthesis and Modelling*, held at **Bangalore**, 18-20 January, 1999 by M.M. Sarin , R. Rengarajan and S. Krishaswami.

171. "Sediment deposition rates on the continental margins of the eastern Arabian Sea using ^{210}Pb, ^{137}Cs and ^{14}C", at the *International Atomic Energy Agency Conference on*

Marine Pollution, **Monaco**, October 5-9, 1998 by B.L.K. Somayajulu, R. Bhushan, A. Sarkar, G.S. Burr and A.J.T. Jull.

172. "Search for extinct aluminium-26 in the Piplia Kalan eucrite", at the *61st Meteoritical Society Meeting, Dublin*, **Ireland**, July 27-31, 1998, by G.Srinivasan, J.N.Goswami and N.Bhandari.

173. "Sm-Nd systematics and initial $^{87}Sr/^{86}Sr$ in the Piplia Kalan eucrite", at the *30th Lunar and Planet. Sci. Conference*, **Houston**, Texas, March 15-19, 1999, by G.Srinivasan, D.A.Papanastassiou, G.J.Wasserburg, N.Bhandari and J.N.Goswami.

174. "^{26}Al-^{26}Mg and ^{53}Mn-^{53}Cr systematics in the Piplia Kalan eucrite", at the *30th Lunar and Planet. Sci. Conference*, **Houston**, Texas, March 15-19, 1999, by G.Srinivasan, D.A.Papanastassiou, G.J.Wasserburg, N.Bhandari and J.N.Goswami.

175. "Magnesium-Aluminium study of hibonites within a chondrule like object from sharps (H3)", at the *61st Meteoritical Society Meeting, Dublin*, **Ireland**, July 27-31, 1998, by G.Srinivasan and A. Bischoff.

176. "Strontium isotope systematics of Amba dongar carbonatite - alkaline complex, Western India", at the *Ninth International Conference on Geochronology, Cosmochronology and Isotope Geology*, **Beijing**, China, August 20-26, 1998, by J.R.Trivedi and J.S. Ray.

177. "Palaeomonsoon record of the last 3400 years from speleothems of tropical India", at the *Symposium on the Quaternary of India*, Nagpur University, Nagpur, 19-21 February, 1999, by M.G. Yadava and R. Ramesh.

178. "Late Holocene environmental records from stable isotopes in tropical speleothems", at the *PAGES Open Science Meeting*, London, **UK**, 20-23 April, 1998, by M.G. Yadava and R. Ramesh.

179. "Luminescience spectral measurements on meteorites", at the *XXX Lunar and Planet Sci. Congress.*, **Houston**, 1999, by A.J.C. Zink, M.R. Krbetschek, T. Trautman, A.K. Singhvi and W. Stolz..

Library

180. "Going Digital.. Developing digital Library at PRL ", in 49th International Federation for Information and Documentation Conference and Congress, New Delhi, 11-17 October, 1998 by Nishtha Anilkumar.

Electronics Laboratory

181. "Neural Network and Pattern Recognition", at the Course on Advance Computing held at Sardar Patel University, March 1999, by H. S. Mazumdar.

In addition a large number of faculty members gave course of lectures at the first **Post Graduate Course on Space Science** of the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTE-AP). The details are given in the next page.

Lectures Given During 1998-99

At the First Post Graduate Course in Space Science

Name	No.of Lectures	Topics
Dr. R. Sridharan	10	Optical Aeronomy, Airglow, Photometry, Spectrometry Imaging
Dr. D. K. Chakrabarty	10	Global Warming
Dr. H. S. S. Sinha	5	Theory of Langmuir Probe, Electric Field Double Probe, Retarding Potential Analyser, Mass Spectrometer & Vapour Release Experiment
Dr. A. C. Das	5	Magnetospheric Processes
Dr. Shyam Lal	10	Ozone Chemistry
Dr. Ashok Ambastha	5	Sun and Solar Wind
Dr. N. N. Rao	10	Plasma Physics
Dr. R. Ramesh	10	Climate Modelling
Dr. U. C. Joshi	10	Instrumentation for Astronomy
Dr. S. P. Gupta	5	Balloon-borne Techniques of Conductivity, Electric Field
Dr. A. Jayaraman	10	Aerosols & Radiation Effects
Dr. Y. B. Acharya	6	Lidar and Optical Instrumentation
Mr. R. N. Misra	5	Rocket-borne Techniques and Instrumentation
Dr. R. Sekar	6	Numerical Simulation & Modelling
Dr. S. A. Haider	4	Planetary Atmospheres
Dr. Vijay Kumar	5	Laboratory Astrophysics

Science at PRL

The Astronomy and Astrophysics Division is located at Thaltej (7 kms from main campus of PRL), and operates an observatory at Mt. Abu equipped with a 1.2m IR telescope and a host of world-class state-of-the-art back-end instruments - IR camera (NICMOS-3), large format CCD camera, Imaging Fabry-Perot spectrometer grating spectrographs, optical and IR polarimeters, high speed dual channel IR photometer etc., to cater to the needs of astronomers. The Udaipur Solar Observatory (USO) is equipped with three solar telescopes to make observations on Sun. A GONG experiment operates to probe the interior of Sun using helioseismology. USO also plans to put an X-ray experiment (SOXS) on satellite platform to study the activity on Sun in soft X-rays.

Co-ordinated Simultaneous Monitoring of Mrk 501 in Optical and γ-rays

The BL Lac object Mrk 501 exhibited remarkable burst and flaring activity in Gamma rays during April-May 1997. Attempts were made worldwide to catch this activity in various wavelength bands. The simultaneous observations of Mrk 501 are important as these will throw light on the possible nature of these variable sources. In a coordinated effort, this object was monitored in optical from Mt. Abu IR Observatory using photopolarimeter mounted at the Cassegrain focus of 1.2 m telescope. At about the same time, observations were also made in γ-rays using TACTIC-BARC facility in Mt. Abu. The optical observations conducted showed increase in optical polarization during this period. The results obtained from TACTIC, an array of 4 Cerenkov telescopes, established that Mrk 501 was in high phase of activity in γ-ray emission during this period **(Fig.1.1)**. Polarisation observations in visual region made during the same period showed an increased degree of polarisation, suggesting that a common phenomenon may be responsible for their generation.

(U.C. Joshi, K.S. Baliyan, Shashikiran Ganesh and M.R. Deshpande)

The Study of Variability in BL Lac Objects

The study of variability in BL Lac Objects, Mrk 421, Mrk 501, OJ287, PKS0208-512 and BL Lac has been a field of immense activity during the last decade of the millennium. We continue to monitor these objects from Mt. Abu using optical photo-polarimeter, CCD and NICMOS-3 IR array mounted at the Cassegrain focus of the 1.2m telescope. Large amount of data has been obtained which is being analysed. Some of these objects, Mrk 421 and Mrk 501, have shown flaring activity during this period. We have also been involved in the simultaneous multiwavelength monitoring campaign of PKS0208-512 which was observed during December 1998. These studies will help us to understand the physical processes behind the huge energy generation in the central engine.

(U.C. Joshi, K.S. Baliyan, M.R. Deshpande and Shashikiran Ganesh)

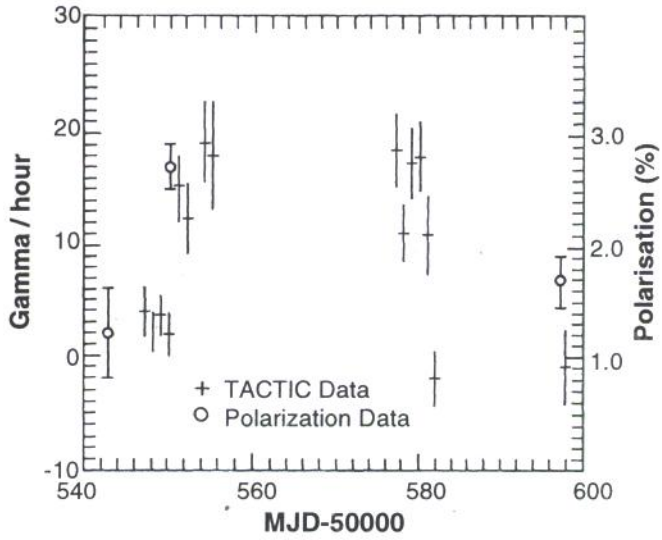

Fig1.1 In a coordinated simultaneous observational campaign on Mrk501, the increase in the degree of polarisation (Mt. Abu-PRL) is shown alongwith high acivity in gamma-rays detected by BARC facility.

Photometry of Starburst Galaxies

A multiband (UBVRIHα) study of starburst galaxies was carried out based on CCD imaging from the 1.2 m Gurushikhar telescope. Twenty starburst galaxies from the Markarian lists were studied under this program and their morphological and structural studies were carried out.

The morphology of the galaxies was studied through various broad bands, narrow-band Hα and colour maps.

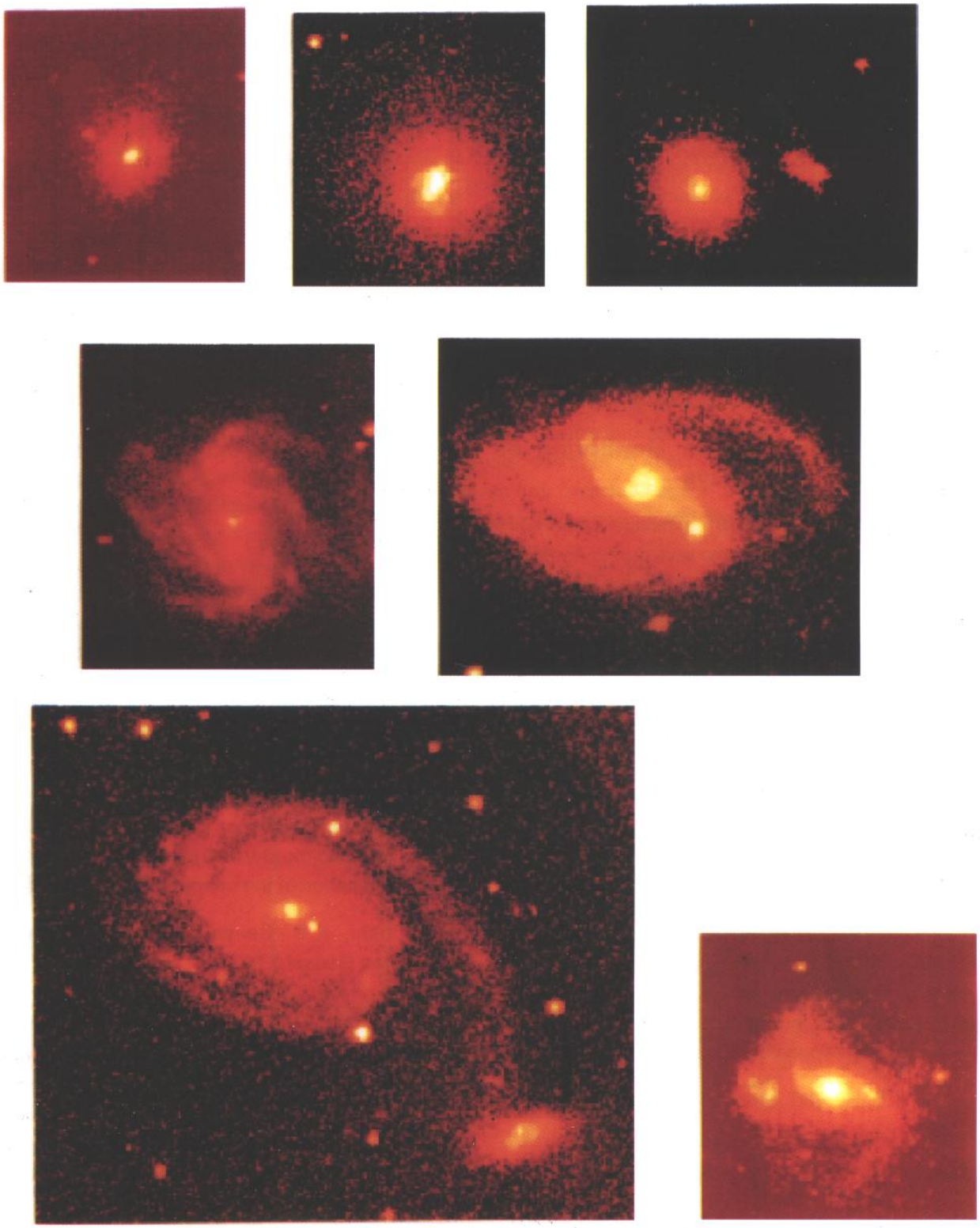

Fig. 1.2 Some of the sample galaxies depicting the varied morphologies. Left to right : top panel : Mrk 14, Mrk 439, Mrk 1308; middle panel : Mrk 781 and Mrk 799; bottom panel : Mrk 1134 and Mrk 1379. North is at the top and East to the left.

This study revealed that starbursts occur in a variety of morphological environments **(Fig.1.2)**. The galaxies in which the starburst phenomenon is seen can be broadly grouped into S0's/E's, spirals and irregulars. Starburst activity as indicated by blue colours and Hα emission is seen predominantly in the central region of the galaxies. However, activity is not only confined to the central kpc, but is also found in the form of circumnuclear rings, at the ends of bars or even globally. Except in the case of Mrk 439, the line emission and the blue regions are coincident indicating that the same episode of star formation is responsible for both these observed results.

The structural properties of the underlying galaxies were studied using ellipse fitting techniques. Isophotal twists were detected in all the S0's/E's galaxies in the sample. Signatures of dust were found in the central regions of Mrk 1379, Mrk 439 and Mrk 1134. A strong dust lane was found in Mrk 449. Besides these, all the other objects appear to be relatively dust free along the line of sight. Ellipse fitting analysis reveals variety of fine structure indicative of mergers, hidden distortions like bars, rings of star formation, etc. Spiral arms extending right into the nuclear region were found in Mrk 363. We detect secondary bars in Mrk 213 and Mrk 1194.

(Aparna Chitre and U.C. Joshi)

Optical Follow-up of the Gamma Ray Bursts

The Gamma Ray Burst phenomena is the hottest issue in astronomy these days. It is due to several reasons - one of them being the scale of energy emission involved in a typical GRB. Due to the accurate localization of GRBs by the Dutch-Italian satellite BeppoSAX, optical follow up of the afterglow has become possible in recent time. In an attempt to understand the source of such high energy, theory of which is not at all understood properly, PRL group has joined the Caltech group - REACT to follow the optical after glow of GRBs. We detected one such phenomenon - after glow of GRB990123 during optical observations from Mt. Abu on the night of January 24-25, 1999. The source was very faint and observations were made in I band using 1K x 1K CCD. The source has been detected at a level of 20.8 mag in I-band **(Fig.1.3)**. We also tried to observe another such event GRB990506 on 7 May 1999

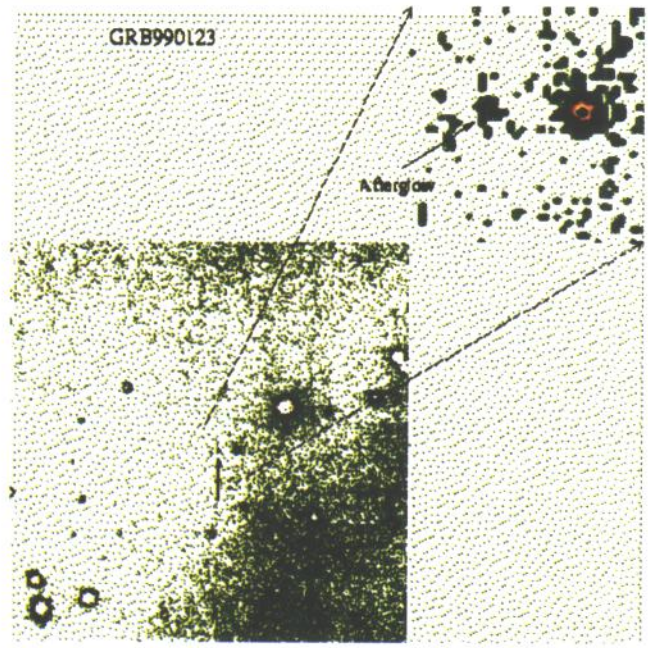

Fig.1.3 Shown here is the optical afterglow of the Gamma Ray Burst GRB990123 detected by using CCD observations in I band (20.8 mag) from Mt. Abu IR Observatory during the night of 24/25 January, 1999.

using NICMOS-3 array. We could image several stars in the field but source was too faint to be detected in near infrared. We intend to continue monitoring of the GRBs.

(K.S. Baliyan, B.G. Anandarao, U.C. Joshi and V. M. Shah)

Study of Young Open Clusters

Clusters in the central part of the galactic disk are embedded inside the molecular gas and dust. These young stellar objects can be classified in different categories based upon their infrared excess and spectroscopic character. This classification may be taken to represent phases of early stellar evolution - from protostar to young main sequence star.

In order to understand the early stellar evolution and star formation, we have taken up the study of extremely young clusters using NICMOS-3 IR array at the Mt. Abu Observatory. Some clusters have already been observed and rest will be taken up in the next season.

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

Shocked Molecular Hydrogen Emission in RNO 91

RNO 91 is one of the only two known pre-main sequence stars in the L43 dark cloud in Ophiuchus complex. It is classified as a M 0.5 type T Tauri star. A mild outflow driven by the star was identified at millimeter wavelengths but so far no optical/infrared emission has been reported in the outflow. Using the NICMOS grating spectrometer (R=1000) at the 1.2 m Mt. Abu Infrared Telescope, we have detected the Molecular Hydrogen v = 1-0 S(1) vibrational line at 2.121micron from this star. The emission is extended spatially upto 9 arcsec in the north-south direction (**Fig.1.4**). The asymmetrical extents in the north-south direction are due to the tilted disc around the star that partially obscures the northern flow. An outflow rate for mass of 4.2 X 10^{-8} $M_{\odot}$/yr has been estimated from the H_2 emission flux. Narrow-band images taken through the H_2 1-0 S(1) and Br filters (from service observations at the 3.6 m UKIRT, Hawaii made in collaboration with Dr. C.J. Davis of Joint Astronomy Centre, Hilo, Hawaii, USA) revealed very clearly a tilted disk and bipolar outflow structure that agrees with the earlier observations and models.

(B.G. Anandarao and M.S. Nandakumar)

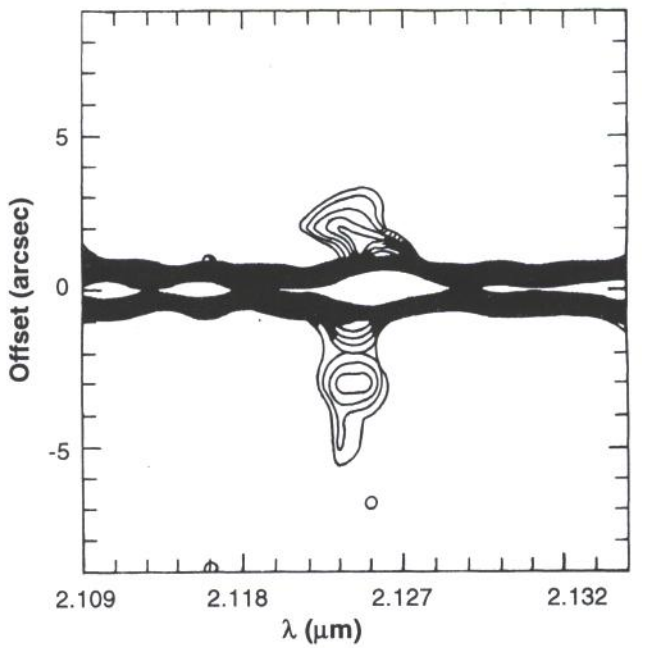

Fig.1.4 Contours of H_2 .122 μm line from RNO 91 spectrum showing the extended emission. Notice the different lengths of emission in the N - S from the centre that indicates the tilt of the outflow axis.

High Angular Resolution Study of Mira Variable R Leonis

Studies of Mira variables are of great importance in stellar astrophysics as these are pulsating stars undergoing rapid mass loss (10^{-7} - 10^{-5} $M_{\odot}$/yr) thereby enriching the interstellar medium. Accurate determination of sizes and shapes is required to resolve problems related to the mode of pulsation and the exact mechanism of mass loss. Therefore, lunar occultation observations carried out at Gurushikhar on the oxygen-rich Mira variable R Leonis are very significant. Observations were made with a narrow band filter at 3.36 μm with a bandwidth of 0.05 μm. A uniform disk angular diameter of 39 ± 3 milliarcseconds at the visual variability phase of 0.17 was derived. This value yields an effective temperature of 2257 ± 110 K and

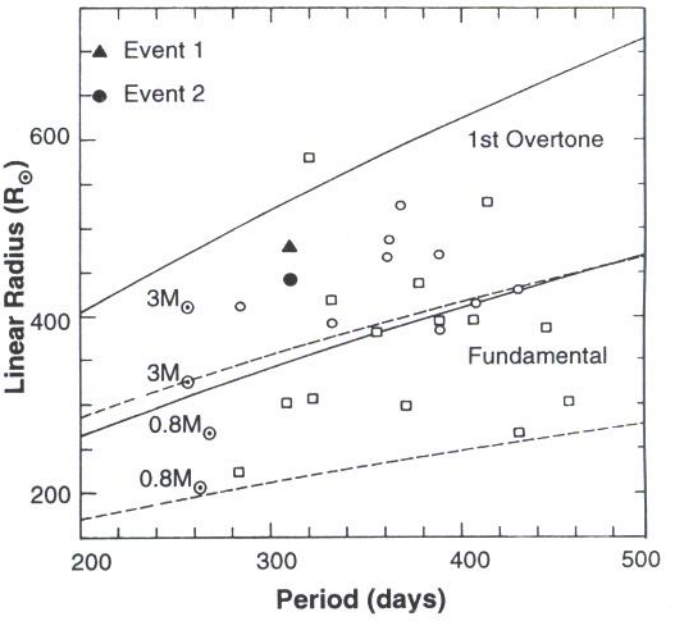

Fig.1.5 A plot of linear radius versus period of pulsation from Mira variables. The closed triangle and circle represent our data. The lines indicate Ostelie-Cox model for the mass range $0.8M_{\odot} < M < 3.0 M_{\odot}$ for both fundamental (dotted line) and first overtone (solid line) modes. Over plotted are the 2.2 micron data (open squares) and visible Mira data (open circles) obtained by other observers.

using the recent values of parallax translates to a linear radius of 478 ± 50 $R_\odot$ (**Fig. 1.5**).

As part of a collaborative program we have compared our 3.36 μm observations with the 2.2 μm occultation observations on the same star obtained by the Arcetri group, Florence, Italy at Calar Alto at visual variability phase of 0.44 of the same cycle. The 2.2 μm observations yield a uniform disk diameter of 34 ± 2 mas. Taken together with the 3.36 μm observations, the implication is that in the near infrared angular diameter variation of R Leo due to pulsation is substantially smaller than in the optical region. Probably we are detecting only the true continuum variation in the IR observations.

(T. Chandrasekhar, A. Tej and N.M. Ashok)

Quadrupolar Nature of the Planetary Nebula NGC 4361

The planetary Nebula NGC 4361, classified as a multiple shell nebula having irregular structures in the outer shell with the central star suspected to be a spectroscopic binary was investigated to determine the nature of its progenitor. Imaging Fabry-Perot Spectroscopic (IFPS) observations were made on the nebula in the [OIII] 5007 A at the 1.2 m MIRT at Mt. Abu. Most of the 90 or so line profiles obtained show a red or blue asymmetry. The most striking feature is that the shape of the line profiles changes from red to blue asymmetry over two very sharply defined linear axes across the nebula, separated by 70°. A synthetic line profile code was developed assuming a 3D model for the nebula and compared with observed profiles at corresponding spatial positions. A remarkable match was found between the two, confirming our assumed 3D model which proposes a quadrupolar morphology - one of the very rare occurrences. This morphology can be caused by a precessing disc around the progenitor system and a two-epoch mass loss. The progenitor mass is estimated to be more than 2.4 $M_\odot$.

(B.G. Anandarao and C. Muthu)

Near IR Spectroscopic Studies of Classical Novae

The programme on Classical Novae has been supplemented by the spectroscopic observations to understand the physical conditions in the gaseous ejecta as the JHK bands (1 to 2.5 μm) contain strong emission features from ions of varying ionization potentials. Novae Sagittarii 1998 was followed during the period April - June 1998. The infrared spectrum of this nova is dominated by emission lines of hydrogen and accompanied by lines of neutral carbon, oxygen and nitrogen. The 1.129 μm OI line excited by Lyman fluorescence is prominently seen in our first spectrum obtained in April 1998. In addition, the OI line at 1.316 μm is also detected indicating the presence of UV continuum fluorescence. The detection of FeII line in IR spectra supports the classification of the nova based on optical spectra as FeII class.

(N.M. Ashok, T. Chandrasekhar and U.S. Kamath)

Near IR Studies of Recurrent Nova U Scorpii

The recurrent nova U Scorpii is distinguished by its extremely rapid rise to and decline from maximum. The sixth recorded outburst of U Sco was reported on 25 February 1999 and soon after this announcement an observing programme was carried out from March 4 to 7 at Mt. Abu IR observatory. Infrared observations were obtained using PRL NICMOS Camera. We have obtained the first J band spectra of this unique object at a resolving power of 1000. The Paschen β emission line is clearly detected and shows changes during the period of our observations. Analysis of the data is in progress.

(U.S. Kamath and N.M. Ashok)

Near IR Spectroscopic Studies of Algol Binaries

One of the problems usually encountered in the light curve studies of Algols is that the temperature of the secondary star, derived from the analysis of photometric light curves at different wavelengths differ significantly. To overcome this problem we are taking the Near IR spectra and photometry of eclipsing binary stars in the JHK wavebands, for which light curves are existing or being observed. The model spectral distribution of the system at different phases when compared with the observed continuum spectra provide direct detection and help quantifi-

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cation of the circumstellar matter. The observations have been done with a NICMOS3 near IR array and the 1.2m Gurushikhar IR telescope.

(Watson P. Varricatt and N.M. Ashok)

Photometric Study of the K band Light Curve of δ Lib

δ Librae is a bright interacting binary system of the Algol type, which is formed as a result of large scale mass transfer. Though, it is one of the brightest among the Algols, very few photometric studies are done on this star. The first K band (2.2 μm) light curve is obtained for this system with the 1.2m Gurushikhar Telescope and an LN_2 cooled near IR photometer. Nearly 1100 individual observations are done with satisfactory coverage of orbital phase. Preliminary analysis of the light curve is done. The light curve fits well for a semi-detached configuration and the secondary is an evolved star. The primary is underluminous and cooler for a main sequence star of the same mass. The re-analysis of the V and B band data of this star with the same model also agrees well with the results from the K band light curve. The K band light curves show day-to-day variation, which shows the presence of circumstellar matter.

(Watson P. Varricatt and N.M. Ashok)

High Resolution Studies of Be Stars

An observational programme to study the emission spectrum of Be stars at high resolution has been initiated. During the last observing season between April 1998 to April 1999, the Hα (6563 Å) spectra of 45 Be stars have been obtained with high signal to noise ratio. The spectra have been obtained using the fibre linked Grating Spectrograph (FLAGS) at the 1.2 m Gurushikhar telescope. From the high resolution spectra, modelling will be done to account for the intrinsic shape of the profiles and also for variability in the profiles. It is also intended to propose general classification schemes for the nature of the profiles.

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

Near IR Observations of Comet Hale-Bopp

Near Infrared photometric observations at J, H and K filter bands were carried out on the 1.2 m telescope at Gurushikhar for eight nights during both the pre-perihelion and post-perihelion phase of Comet Hale Bopp (C/1995 01). The effective temperatures derived from IR photometry are substantially higher than the equilibrium blackbody temperatures at the same heliocentric phase. The ratio of color temperature to the blackbody temperature called superheat(s) as derived from our observations has a value of 1.86 in the post perihelion phase consistent with other preperihelion observations of this comet. These large superheat values imply that a substantial fraction of the coma grain population are made up of small hot grains with radii < 0.5 microns atleast for a short period around perihelion. Later observations point to a depletion of the small hot grains. The derived value of the albedo for Comet Hale-Bopp is 0.4, consistently higher than corresponding values of other comets, and may have contributed to the unusual brightness of Comet Hale-Bopp.

(T. Chandrasekhar, N.M. Ashok, A. Tej, S. Mondal and P.V. Watson)

Pulsar Observations

PSR 0950+08 has been observed almost daily with the Rajkot radio telescope for the last one year. These observations have shown the highest frequency of occurrence of giant pulses seen from any known pulsar. Large fluctuations in the intensity levels of individual giant pulses and in their occurrence rate per unit interval of time are seen during a single day's observations, as well as from one day to the next. After eliminating instrumental, ionospheric, interplanetary and interstellar diffraction and refraction scintillation effects as the cause, we conclude that these intensity variations are intrinsic to the pulsar. Observations of this source were proposed at the Westerbork Radio Telescope (Netherlands) for which the telescope time was granted. As a result the source was successfully observed simultaneously on three different occasions at the Westerbork Radio Telescope (Netherlands), Ooty Radio Telescope, and the Rajkot Radio Telescope. Data reduction is being done.

(Ashok K.Singal, Hari Om Vats and M.R.Deshpande)

Interplanetary Propagation of Coronal Mass Ejections (CMEs)

We investigated several CMEs associated with active regions, e.g. NOAA 7590, 7646 and 8038 etc. and their propagation in the interplanetary medium using interplanetary scintillation at 103 MHz and found that the plasma density enhancements upto 36 times are present in the IPM during CME events. Using diffractive-refractive scattering approach, the parameters of the plasma irregularities are derived. From the limited case analysis it appears that the plasma density enhancements seem to relate directly with the duration of geomagnetic storms. Detailed analysis is in progress to establish the relationship of geomagnetic disturbances with plasma disturbance in the interplanetary medium.

(Hari Om Vats, Rupal Oza, Rajmal Jain, K.N. Iyer, Som Kumar Sharma and M.R. Deshpande)

Study of Solar Generated Transient Phenomena in the Interplanetary Medium

Interplanetary scintillation (IPS) observations made using the Ooty Radio Telescope (ORT) in India and the Nagoya University four station IPS system in Japan, both operating at 327 MHz, show the presence of many solar wind transients in the IPS data. In general, it is found that both the solar wind velocities and the relative scintillation indices (g - values) are enhanced during the passage of a transient. We have identified a number of these events and tried to trace their origin back to the Sun.

In a coordinated international campaign for observing the sun for one full solar rotation in August 1998 (whole-sun-month II), daily IPS observations were carried out (using the ORT) on a grid of about 80 scintillating sources. In many cases studied in this period, type II radio bursts associated with solar flares were reported by ground radio observatories. **Figure 1.6** is a sample polar plot of velocities measured during the whole-sun-month campaign. This work was carried out in collaboration with Dr. V. Balasubramanian, RAC, Ooty; Prof. S. Ananthakrishnan, NCRA, Pune, and Dr. Murray Dryer of NOAA, USA.

(P. Janardhan)

Photoionisation Cross-sections of Fe XVII Ion

The radiative and non-radiative atomic data on the ions of iron are very important for many applications in astrophysics - such as the analysis of X-ray spectra of cataclysmic variables, X-ray binaries and AGNs, plasma modelling, etc. The lack of good quality data results in poor modelling of their environments. Keeping this in mind, photoionization cross sections of the Fe XVII ion from its ground level $2s^2\ 2p^6\ ^1S_0^e$ are calculated in the intermediate coupling using Breit-Pauli R-matrix method. The C-I wave function are used for the lowest three target levels $2s^2\ p^5\ ^2P^0_{3/2,\ 1/2}$ and $2s^2\ 2p^6\ ^2S_{1/2}$ included in the basis function expansion. The cross sections below the highest N-electron threshold are dominated by the Rydberg series of resonances. Such data is required for a number of excited states as well. Part of this calculation was completed during the visit (of KSB) to Kansas State University.

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

Infrared Imaging Fabry-Perot Spectrometer

The technique of Imaging Fabry-Perot Spectrometer in the visible region is extended to infrared regions using NICMOS camera with a Fabry-Perot etalon put outside the Dewar in ambient condition. We commissioned a IFPS in the infrared region between 2-2.5 μm (NIFS) and a FP detector. A set of narrow band filters (inside the dewar) can be used for order-sorting. The NIFS can be used as a spectrometer for velocity mapping at a resolution of about 90 km/s (the instrumental width is 200km/s) or as a spectrophotometer to map regions of emission line in the range 2-2.5 μm. Several rounds of observations have been made at the 1.2 m MIRT, Mt. Abu on some bright diffuse nebulae associated with star forming regions. **Figure 1.7** shows the NIFS images of the Orion nebula in several scanning stages around the H_2 v = 1-0 S(1) 2.121 μm vibrational transition showing the bizarre structures in the emitting regions.

(B.G. Anandarao, M.S. Nandakumar, N.S. Jog, R.T. Patel and F.M. Pathan)

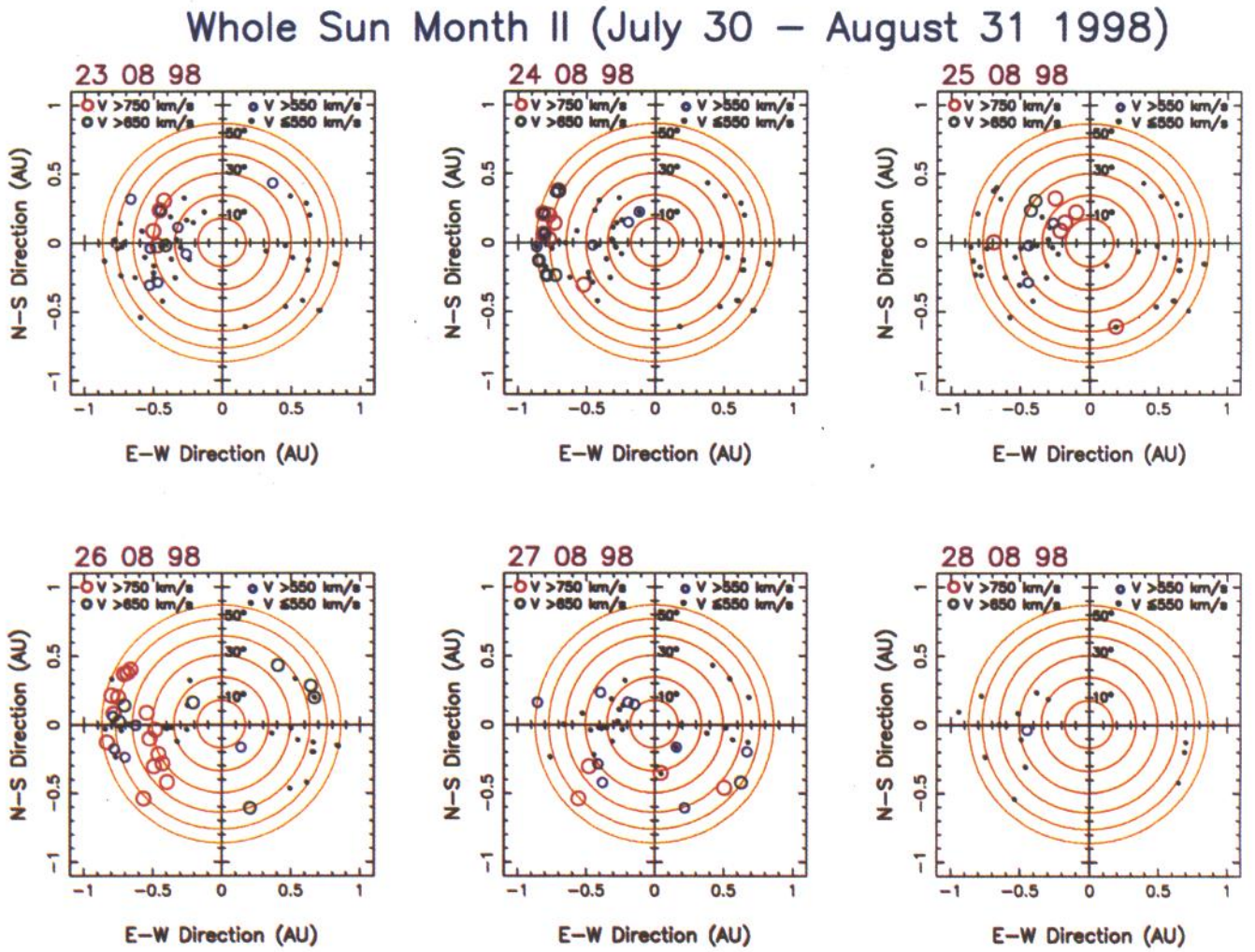

Figure 1.6 The plot shows the sun at the centre. The concentric circles are circles of constant solar elongation while the different velocities are indicated by differently coloured markers as indicated in the diagram. The axis is also marked in AU in the North-South and East-West directions.

FLAGS - A Fibre Linked Astronomical Grating Spectrograph

A fibre-linked grating spectrograph has been designed and developed in house at PRL for astronomical studies. The spectrograph has a Czerny Turner configuration with f/10 optics of 1.5 m focal length. The resolving power of the instrument is about 10,000 over the visible region (4000-7000A). Optical fibres have been used to guide light from the telescope to the spectrograph. FLAGS is being used at the 1.2 m Gurushikhar telescope, for the study of Be stars, since it was made operational in March 1998.

(D.P.K. Banerjee, S.D. Rawat, F.M. Pathan and B.G. Anandarao)

Flux Emergence, Motion and Cancellation in the Flaring and Non-flaring Locations

An active region NOAA 8038, was observed during May 10 - 13, 1997 using USO solar video magnetograph. Prior to the onset of an 1N/C1.3 flare on May 12, 1997/

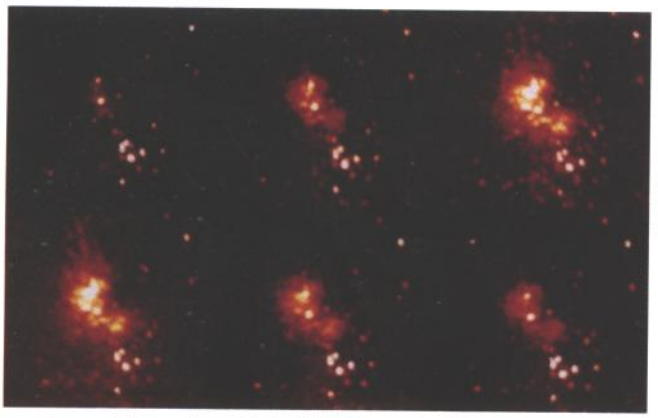

Fig.1.7 Orion Nebula through different steps of the IR Fabry-Perot Spectrometer

04:45 UT, emergence of new fluxes was observed. Combining the USO and SOHO magnetograms, large horizontal velocities in the range 300 - 800 m/s were estimated for the network photospheric magnetic fluxes. Such large motions can easily build sufficient magnetic energy required for flares, however, the problem remains to explain the onset of the energy release process and to distinguish between the flaring and non-flaring locations. Role of magnetic field gradients, and motion of fluxes in the flaring area is examined using the near-simultaneous chromospheric and magnetic field observations.

Rapid changes in magnetic field structure due to flux motions lead to dramatic transient events at rather large scale as seen on March 15, 1999 **(Fig.1.8, back page)**. Apart from filament eruption, energy release process leading to solar flares is also triggered. Significant changes in the magnetic field configuration of another active region NOAA 8032 were observed due to the emergence of new magnetic fluxes, which resulted in strong magnetic field gradients. It produced a number of sub-flares and two C-class flares during the 8 - 9 hours of its rapid evolution on April 15, 1997. EFR driven reconnection of field lines and flux cancellation perhaps produced repeated sub-flares. The two adjoining locations of opposite polarities flux regions near the flaring site showed increase in one type of flux while a decrease occurred in the opposite polarity. The potential field calculation showed rearrangement of the field lines during the evolution of the active region. Similarly, loop formation and reorientation were also observed in the transition region loops.

(Shibu K. Mathew and Ashok Ambastha)

Near-IR and Optical Study of Quiet and Active Solar Regions

High spectral and spatial resolution observations were carried out from NSO/Sac Peak Observatory during June 1998, with an aim to study the sub-photospheric (below τ_{5000}~1 layer) thermal structure of active and quiet solar regions. Observations were made in 1.6 micron near-IR and at 0.4 micron in the violet continuum of the optical waveband. Even though the geometrical depth is rather small (only about 35 km), the energy balance of the sun changes rapidly between convective to radiative transport in this short height interval. In addition to intensity images, we obtained the corresponding spectra, and magnetic field data. It is intended to intercompare the near-IR and optical observations, and identify the best wavelength window for subphotospheric studies. The modification of the thermal structure due to magnetic field will also be investigated using the data obtained at quiet and active locations. This work is being carried out in collaboration with K. S. Balasubramaniam, NSO/Sac Peak Observatory.

(Ashok Ambastha and Debi Prasad)

Multiwavelength Study of the Flare of 1997 May 12

NOAA 8038 has been studied using a movie of MDI/SOHO magnetograms, which revealed that opposite polarities approached towards each other. A small north polarity flux was being ejected out from the major north polarity region at a quasi-periodicity of ~10 hrs during 1997 May 10-13. Collision of one such ejected flux with a new south polarity flux on 1997 May 12/04:40 UT perhaps led to a long duration 1B/C1.3 solar flare, associated with a blast wave and a CME, as seen by EIT/SOHO. The multiwavelength observations of this flare in Hα, X-ray, radio, and the corresponding interplanetary scintillation and ionospheric absorption data indicated that the flare energy release occurred in two stages - at 04:42 and

04:47 UT. A model for the interpretation of the two stage energy release process has been proposed, which also explains the CME, the type II radio burst and the enhancement of interplanetary scintillation index. This work was done in collaboration with Y. Hanaoka, K. Shibata, S. Sharma, V. Bogod, S. Tokhchukova, S. Nagai, E. Sagawa, K. N. Iyer and R. Oza.

(Rajmal Jain, Lokesh Bharti, Hari Om Vats, M. R. Deshpande and H. Chandra)

Study of p-modes Around a Sunspot

A time series of GONG Dopplergrams from Udaipur and Big Bear sites has been used to simultaneously measure velocity fluctuations in a sunspot (NOAA 8038) and the quiet photosphere during 1997 May 10-14. The power spectrum for the quiet region follows an asymptotic Lorentzian distribution, whereas a significant departure from such profile is observed for the sunspot. Power of pre-dominant p-modes is found to be 39-52% less in the sunspot as compared to quiet photosphere **(Fig1.9)**. A relative frequency shift of the order of 70-300 μHz has also been found corresponding to the power envelope of these modes. It is observed that this shift corresponds to the magnetic field in the sunspot. However, a larger frequency shift (300 μHz) of the order of 10σ level of p-modes was found on May 12. This may perhaps be attributed to the solar flare that occurred in the sunspot active region under consideration.

(Brajesh Kumar, Rajmal Jain , S. C. Tripathy, H. O. Vats and M. R. Deshpande)

Variation of Solar Rotation Period from Core-to-Wing of UV Lines

We are studying the influence on solar rotation periods due to variation of spectral irradiance from core to wing of a few selected UV lines observed by SBUV/2 instrument onboard NOAA 11 satellite. The time series of spectral irradiance at the core and at one nm away from the center in red and blue wings of the lines - Fe XII; Mg II; Mg I; Si I; Fe XIII; FeI N; Ca K, and Fe XI, for the period 1991-93 was subjected to Fourier Transform to obtain the power spectrum of spectral irradiance. This power spectrum has revealed several interesting results about the solar rotation period, and its variation with wavelength of observation.

(Rajmal Jain and Lokesh Bharti)

Photospheric Oscillations using G-band Filtergram Time Series

High spatial resolution G-band (4305 A) filtergrams obtained at Sac Peak, USA during 7-16 October, 1998 are studied. Time series of about 3-5 hrs obtained at a

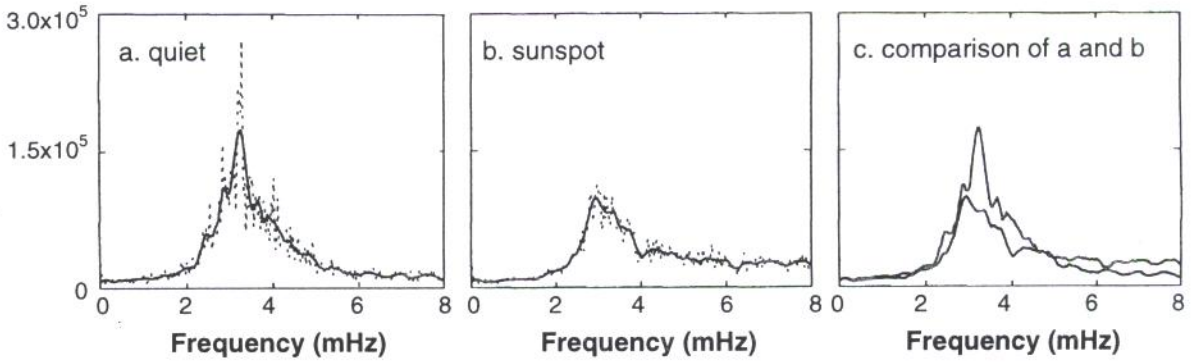

Fig1.9 Average power spectrum for quiet photosphere and sunspot (dashed curve) on May 12,1997 for Udaipur GONG network station. The solid line shows the Savitzky-Golay digital filter fit. A comparison of the two power envelopes reveals the relative power reduction and frequencey shift in the sunspot.

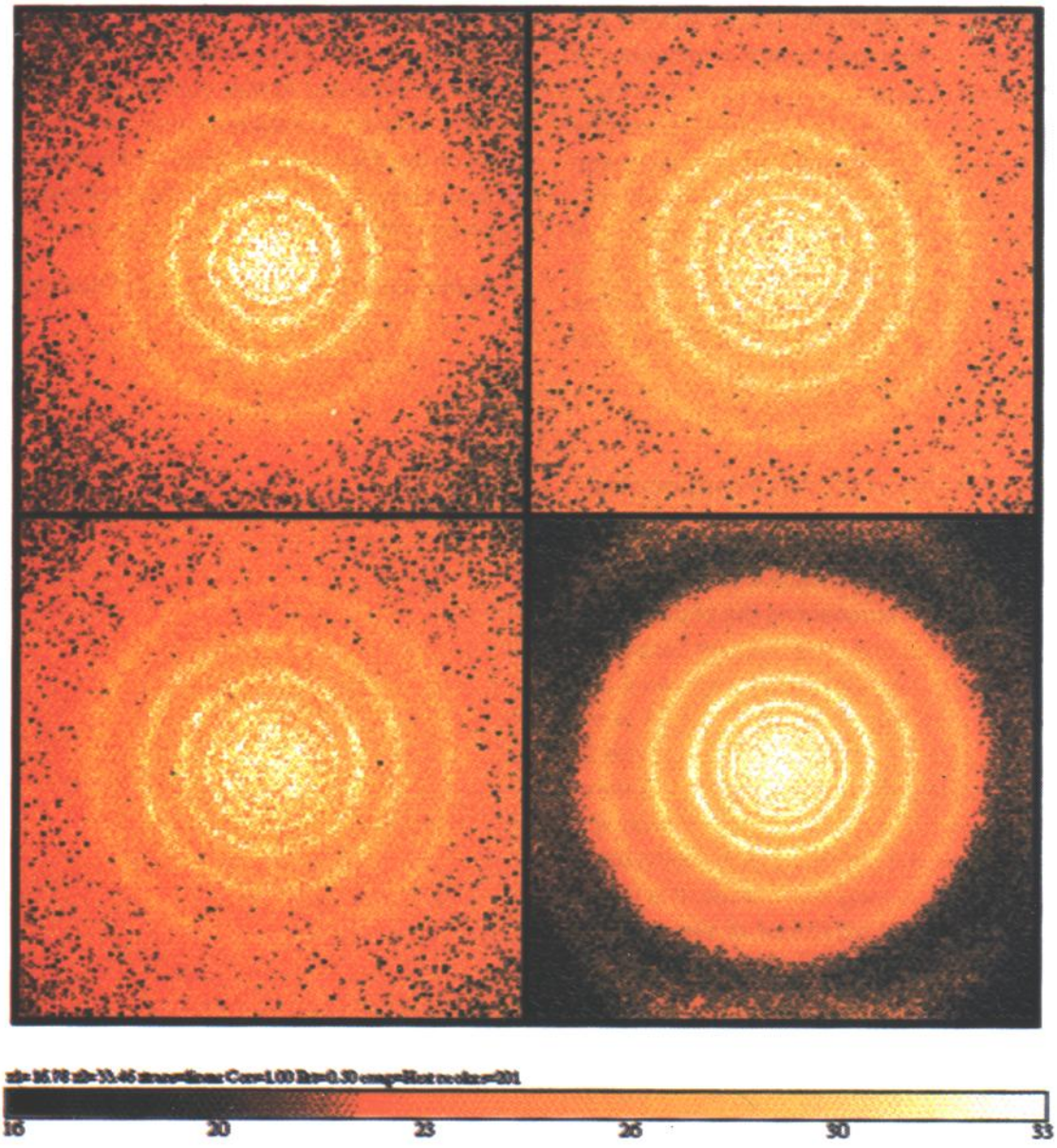

Fig.1.10 Sample (logarithmic) power spectra as a function of k_x and k_y at a fixed frequency. The top panels are for the region centered at equator and Carringion longitude of 60^0, at frequencies of around 3 mHz(left) and 4mHz (right). The bottom left panel is the spectrum around 4 mHz for a region centered at 40^0 N latitude and longitude of 60^0. The bottom right panel is the summed spectrum around 4 mHz for regions centered at the equator. The colour- map is marked with logarithm of the power.

cadence of 5 seconds will be analyzed to study photospheric oscillations in large and small scale magnetic fields. The oscillation periods will be compared with that in quiet photospheric regions.

(Lokesh Bharti and Rajmal Jain)

Ring Diagram Analysis of Near Surface Flows and Velocity Fields

Ring diagram analysis of solar oscillation power spectra obtained from MDI data is performed to study the velocity fields within the solar convection zone as shown

in **Figure 1.10**. The 3-dimensional power spectra are fitted to a model with a Lorentzian profile in frequency to obtain the two horizontal components of flows. This information is then inverted to infer the variation in flow velocity with depth. The resulting velocity fields yield the mean rotation velocity at different latitudes which agrees reasonably with helioseismic estimates. The zonal and meridional flow inferred in the outermost layers also appear to be in agreement with other measurements. This work has been done in collaboration with H.M. Antia and S. Basu.

(S.C. Tripathy)

Solar Cycle Changes in GONG Frequencies

We have looked for possible correlation between the changes in GONG p-mode oscillation frequencies and nine solar activity indices representing the photosphere, chromosphere and the corona. The data set consists of frequencies of the intermediate degree between 2 and 150 for the period 1995 August to 1997 August which corresponds to the declining phase of the solar cycle 22 and the ascending phase of the new cycle 23. The mean frequency shifts show a strong to good correlation with different activity indices; the radiative indices being better correlated as compared to magnetic indices. It is further observed that the temporal behaviour of the solar frequency shifts follow closely the phase of the solar activity cycle.

Since the Sun is not spherically symmetric, the mode frequencies within each multiplet are said to be split and the frequency splittings are now accurately measured. Using the GONG even order splitting coefficients we show that these coefficients vary systematically with solar cycle and are also well correlated with the activity indices. This work is in progress.

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

Changes in p-mode Eigenfrequencies with the Solar Cycle during 1986-1998

The evidence that the oscillation frequencies vary with the solar cycle mostly consist of data for a few years covering a partial solar cycle. Here we use data from different stations for the period 1986 to 1998 to study the changes in p-mode frequencies over a full 11 year solar cycle. We show and further confirm that the frequency shift is a function of frequency only and has no dependence on the degree of the mode. We further investigate the solar cycle parameter that is best correlated with the observed shifts. This work is in progress.

(Brajesh Kumar, Kiran Jain and S.C. Tripathy)

The main aim of the Theoretical Physics Division is to understand the fundamental interactions and basic processes in Nature in both macro- and micro-systems, using analytical and computational techniques. Broadly, the research carried out is subdivided under headings: Gravitation Physics, Atomic and Molecular Physics, High Energy Physics, Nuclear Physics and Plasma Physics.

GRAVITATION PHYSICS

Accretion Disk

Accretion process involves an infalling and rotating gas cloud around a central star. Energy of many very high luminosity astrophysical objects are believed to be coming from such process. According to recent understanding of accreting black hole system, the gas cloud can be optically thin and most of its internal energy is carried to the central black hole. It was found that such a gas cloud can be described by a self-similar solution in the regions far away from the central black hole. However, knowledge of gas dynamics near the black hole is necessary to calculate the spectrum of the accreting system. Therefore, it is necessary to check the validity of the self-similar solution in the region near the black hole. We have developed a pertubative technique which regard the self-similar solution as a back-ground. Effects of non-newtonian potential is regarded as a pertubation over the back-ground. We find that over a certain range of the viscosity parameter, there can be a violation of the self-similarity in the region very far off from the central black hole.

(J.R. Bhatt and A.R. Prasanna)

Photon Propagation in Einstein and Higher Derivative Gravity

In the wave equation obeyed by electromagnetic fields in curved spacetime there are Riemann and Ricci curvature coupling terms to the photon polarisation, which result in a polarisation dependent deviation of the photon trajectories from null geodesics. Photons are found to have an effective mass in an external gravitational field and their velocity in an inertial frame is in general less than c. A consequence of this is that the curvature corrections to the propagation of electromagnetic radiation keep the velocities subluminal provided the strong energy condition is satisfied. We further show that the claims of superluminal velocities in higher derivative gravity, the theories are erroneous and arise due to the neglect of Riemann and Ricci coupling terms in the wave equation, which exists in Einstein's gravity itself.

(S. Mohanty and A.R. Prasanna)

Rotating Compact Objects with Magnetic Fields

We have considered here the structure of the rotating compact objects endowed with a magnetic field in general relativity as models of pulsars. We have discussed structure of rotating stars in the framework of Hartle and Thorne, using different equations of state, and studied their effects on bulk properties of stars. We also consider the possibility of rotating star with a quark matter core. We further analyse the structure of the magnetic field in the interior of the star, as affected by different equations of state as well as due to rotation.

(A. Gupta, A. Mishra, H. Mishra and A. R. Prasanna)

ATOMIC AND MOLECULAR PHYSICS

Form Factor for Transition Between Arbitrary Parabolic Rydberg Stark States

We have shown that the quantum form factor for transition between arbitrary excited states of parabolic coordinate system can be expressed in terms of the Jacobi polynomials. This important result allows several properties of the form factor to be readily deduced from the known properties of the Jacobi polynomials. For example, the structures in the form factors can be understood as essentially arising from the oscillations of the Jacobi polynomials. We have also obtained a formula of the form factor for transition between arbitrary parabolic Rydberg states (large parabolic quantum numbers) without appealing to any quasi-classical results. This formula permits us to examine the validity of quasiclassical results obtained earlier for high Rydberg states. Another advantage of the present formulation is that, using available computer package for the Jacobi polynomials, form factor may be numerically computed for fairly large values (n ~ 1000) of the principal quantum numbers. We have also

obtained a compact algebraic expression for the elastic form factor for circular states.

(D.P. Dewangan)

HIGH ENERGY PHYSICS

Gauge Mediate SUSY Breaking and Neutrino Masses

The neutrino mass spectrum was analyzed under the assumption that (1) soft symmetry breaking terms in the minimal supersymmetric standard model are generated by means of the gauge mediated interactions and (2) R symmetry is violated by bilinear terms. The models essentially contains four parameters which determine three neutrino masses and three mixing angles completely. It is shown that the minimal model cannot provide simultaneous solution to the solar and atmospheric neutrino anomalies but its extensions can do this.

(A.S. Joshipura and S. Vempati)

Neutrino Masses and Trilinear R Violation

We systematically analyzed the neutrino spectrum in the presence of trilinear R parity violating interactions. It was shown that in spite of large number of parameters describing these interactions, neutrino spectrum can be fairly constrained under the assumption that all the trilinear R violating parameters are of the same order of magnitudes. This scenario can simultaneously account for the vacuum solutions to the solar and atmospheric neutrino anomalies without fine tuning in any parameters.

(A.S. Joshipura and S. Vempati)

Gravitationally Violated Lepton Numbers and Neutrino Anomalies

All the global symmetries are supposed to be broken by the gravitational interactions. It is shown that very tiny violations of a global $L_e - L_\mu - L_\tau$ symmetry can account for the solar and atmospheric neutrino anomalies simultaneously. Specific model is proposed which can account for these anomalies purely in terms of the grand unification, weak and the Planck scale.

(A.S. Joshipura)

Radiatively Generated Neutrino Masses

A simple radiative mechanism to describe pseudo-Dirac neutrinos is proposed and analyzed in the context of neutrino anomalies. Starting with a $L_e - L_\mu - L_\tau$ symmetric theory it is shown how one could obtain the right amount of splitting between degenerate states to account for vacuum solution to neutrino anomalies. The presence of the grand unification scale is shown to lead to the scale relevant to explain the atmospheric neutrino anomalies. The model provides a realization of the seesaw mechanism in the context of SU(5) model. In this realization, the overall neutrino mass scale is controlled by the grand unification scale and hierarchy in the masses is governed by the charged lepton masses.

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

The Field Theoretical Approach to Coherence in Neutrino Oscillations

We study the conditions for the existence of neutrino oscillations in the field-theoretical approach which combines neutrino production and detection processes in a single Feynman graph. We find that there are deviations in the oscillation probability formula due to the finite lifetime of the source which produces the neutrinos. This work was done in collaboration with Professor W. Grimus of University of Vienna, Vienna.

(P. Stockinger and S. Mohanty)

Texture of a Four Neutrino Mass Matrix

We propose a simple texture of the neutrino mass matrix with one sterile neutrino along with the three standard ones. It gives maximal mixing angles for $U_e \rightarrow U_S$ and $U_\mu \rightarrow U_\tau$ oscillations or vice versa. Thus with only four parameters, this mass matrix can explain the solar neutrino anomaly, atmospheric neutrino anomaly, LSND result and the hot dark matter of the universe, while satisfying all other Laboratory constraints. This work was done in collaboration with Professor D.P. Roy of TIFR, Mumbai.

(S. Mohanty and U. Sarkar)

Constraints on Background Torsion Field from K Physics

We point out that a background torsion field will produce an effective potential to the K and $\bar{K}$ with opposite signs. This allows us to constrain the background torsion field from the K_L and K_S mass difference, CPT violating K_0 and $\bar{K}_0$ mass difference and the CP violating quantities η_o and η_{+-}. The most stringent bound on the cosmological background torsion $< T^0 > < 10^{-25}$ GeV comes from the direct measurement of the CPT violation.

(S. Mohanty and U. Sarkar)

Optical Activity of a Neutrino Gas

For photons that propagate through a gas of neutrinos with a non-zero chemical potential, the left-handed and right-handed polarization modes acquire different dispersion relations. This is due to the CP and CPT-odd terms induced by such a background on the photon self-energy. We present a detailed calculation of this effect, which does not depend on any physical assumptions beyond those of the standard electroweak model. Some possible cosmological and astrophysical implications of our results are considered in several contexts, including the recent discussions regarding the rotation of the plane of polarization of electromagnetic waves over cosmological distances. This work was done in collaboration with Professor Jose F. Nieves of Puerto Rico, New Mexico and Professor Palash B. Pal of Saha Institute of Nuclear Physics.

(S. Mohanty)

Electroweak Baryogenesis in a Cold Universe

We discuss the possibility of generating the baryon asymmetry of the Universe when the temperature of the Universe is below the electroweak scale. In our model the evaporation of primordial black holes or the decay of massive particles reheats the surrounding plasma to temperatures above the electroweak transition temperature leading to restoration of electroweak symmetry locally. The symmetry is broken again spontaneously as the plasma cools and a baryon asymmetry is generated in the process. This mechanism is not sensitive to the details of the electroweak phase transition and works even when the transition is of second order. This work has been done in collaboration with S. Sengupta and A. Srivastava at the Institute of Physics, Bhubaneswar.

(R. Rangarajan)

CP Violating $Z\gamma\gamma$ and Top-Quark Electric Dipole Couplings in $\gamma\gamma \to t\bar{t}$

Although the standard model (SM) of particle physics is tested extensively in the leptonic as well as hadronic colliders, the area of pure gauge boson couplings is not explored in detail. Deviation of the gauge boson couplings from the SM values could be used to infer the presence of new physics. An effective CP-violating $Z\gamma\gamma$ vertex coming from new physics can give rise to observable CP-odd effects in $\gamma\gamma \to t\bar{t}$. However, in this process one has to contend with a possible extra source of CP violation, viz., the CP-violating electric dipole coupling of the top quark. We study certain asymmetries in the decay-lepton distributions arising from top quark decay in the presence of CP-violating $Z\gamma\gamma$ couplings as well as a top-quark electric dipole coupling. We find that a photon linear collider with geometric luminosity of 20 fb^{-1} can put limits of the order of 0.1 on the imaginary part of the $Z\gamma\gamma$ coupling using these asymmetries. This work was done in collaboration with P. Poulose of TIFR, Mumbai.

(S.D. Rindani)

Discriminating CP Violation in Production and in Decay of Top Quarks in $e^+e^- \to t\bar{t}$

While the standard model (SM) predicts unobservably small CP violation in effective $Wt\bar{b}$, $t\bar{t}\gamma$ and $t\bar{t}\gamma$ vertices, extensions of SM can give rise to larger such effects. These would lead to signatures which can be looked for at future linear e^+e^- colliders. However, since there would be three different sources of CP violation, the simultaneous measurement of the separate contributions of these effects is in principle difficult. The possibility of separating the sources of CP violation for any given CP-odd observable by means of different kinematical cuts

was investigated. The most interesting and useful observables make use of the energy and momentum of the lepton arising from the decay of t or $\bar{t}$. Thus, the effect on cuts on the production angle of a decay lepton and the energy of the lepton in the laboratory frame were studied. Another parameter studied was the longitudinal polarization of the electron beam. It is found that it is possible to choose kinematic regions which would enhance the contribution of one source of CP violation over another in many asymmetries, particularly for the cases which are even under naive time-reversal. In other cases, it may be necessary to study more than one observable to separate these effects.

(S.D. Rindani)

Neutrino Masses with Triplet Higgs Scalars

Neutrinos are massless in the standard electroweak model. However, the present observations at Super Kamiokande indicates a non-zero mass of the neutrinos. This also implies a violation of lepton number. We proposed a new mechanism of providing neutrino masses by introducing a triplet Higgs scalar in the standard model, whose decay can also generate a lepton asymmetry and hence a baryon asymmetry of the universe at a very high scale. This work was done in collaboration with Ernest Ma of the University of California at Riverside, USA.

(U. Sarkar)

Discriminating Models of Neutrino Masses from Leptogenesis

There are few generic models of neutrino masses, namely, see-saw mechanism, triplet Higgs mechanism (proposed by us), radiative Zee-type models, and supersymmetric R-parity breaking models. Since lepton number is violated at different scales in all these models, we find that some of them can erase the baryon asymmetry of the universe through sphaleron interactions. The fact that we exist requires a large baryon asymmetry of the universe, which then prefers the see-saw model and the triplet Higgs model over the other two classes of models. We also propose an extension of the Zee type model to generate a baryon assymetry of the Universe. This work was done in collaboration with Ernest Ma of the University of California at Riverside, USA and Martti Raidal of DESY, Hamburg, Germany.

(U. Sarkar)

Effect of Right Handed Charged Gauge Bosons in Models of Leptogenesis

In left-right symmetric extension of the standard model there are new gauge bosons, namely, the right handed counterparts of the weak gauge bosons. We pointed out that these gauge bosons can have severe effects on the generation of the lepton asymmetry of the universe. In particular, they can wash out the existing baryon asymmetry of the universe in some special cases. This work was done in collaboration with Ernest Ma of the University of California at Riverside, USA and S. Sarkar of the Oxford University, Oxford, UK.

(U. Sarkar)

Test of Special and General Theory of Relativity in K-system

Although special theory of relativity and the general theory of relativity met with tremendous success for ordinary matter, very little is known about their applicability for the strange matter. With an aim to improve this bound we gave a general formalism for testing the special and general theory of relativity from measurements on K-system. While the pendulum experiments could test these theories to an accuracy of 10^{-11}, these theories could be tested to an accuracy of 10^{-21} from the present data available from experimental studies of the K-mesons. This work was done in collaboration with Thomas Hambye of Frascatti, Italy and Robert Mann of the University of Waterloo, Canada.

(U. Sarkar)

Meson Correlators at Finite Temperature

The structure of vacuum in Quantum Chromodynamics (QCD) is one of the most interesting question in strong interaction physics. The evidence for quark and gluon condensates in vacuum is a reflection of its complex nature. Determination of correlation functions of hadronic

currents in such a vacuum state provides rich information regarding interquark interaction as a function of their spatial separation as well as on hadron spectroscopy. We have tried to evaluate equal time point to point spatial correlation functions of mesonic currents at finite temperature. For this purpose we consider the QCD vacuum structure in terms of quark antiquark condensates and their fluctuations in terms of an irreducible four point structure of the vacuum. The temperature dependence of quark condensates is modelled using chiral perturbation theory for low temperatures and lattice QCD simulations near the critical temperature. For the four point function, we assume a simple T-dependence so that it vanishes at T_C. We first consider the propagation of quarks in a condensate medium at finite temperature. We then determine the correlation functions in a hot medium. Parameters such as mass, coupling constant and threshold energy are deduced from the finite temperature correlators. We find that all of them decrease close to the critical temperature.

(V. Sheel, H. Mishra and J.C. Parikh)

NUCLEAR PHYSICS

Results of a O(36) Symmetry Limit for Heavy N ~ Z Nuclei

Continuing our work on the structure of nuclei near proton drip line using symmetry schemes of a boson model with interacting scalar (s) and quadrupole (d) bosons with each carrying spin (S) and isospin (T) degrees of freedom (ST) = (10) $\oplus$ (01), this year PRL scientists analyzed a O(36) symmetry limit of this model with good s, d and sd boson spin-isospin O(6) symmetries (i.e. Wigner's spin-isospin SU(4)'s) and the following results are obtained: (i) low-lying spectra for N=Z even-even and odd-odd nuclei are constructed by identifying all the quantum numbers; (ii) both in the symmetry limit and allowing for mixing, number of T = 0 pairs in the ground states as a function of boson number and isospin is studied and the results are consistent with known shell model predictions; (iii) for N=Z odd-odd nuclei, for the yrast band with (ST) = (01) (say as in ^{74}Rb) the symmetry limit generates a isospin dictated $\Delta J = 4$ staggering in B(E2)'s; (iv) nature of B(E2)'s in low-lying levels depend sensitively on the structure of the E2 operator with respect to $O_{ST}(6)$; (v) it is seen that the two-nucleon transfer strengths give information about high-lying states with O(36) quantum number $\omega = N - 2$; N is boson number.

(V.K.B. Kota)

Embedded Random Matrix Ensembles for Complexity and Chaos in Nuclei

Universal properties of simple quantum systems whose classical counter parts are chaotic, are modelled by the classical random matrix ensembles and their interpolations/deformations. However, recent analysis of information entropy and number of principal components in shell model transition strengths by PRL group, large scale shell model studies by Michigan group for strength functions in particular, spectroscopic calculation for the Ce atom by Australian group etc. brought focus to the importance of embedded Gaussian orthogonal ensemble of random matrices (EGOE(k)), for k-body operators in m-particle spaces, and their deformations in studying finite interacting many particle systems exhibiting chaos. With EGOE strength sums, generated by a transition operator acting on a eigenstate with energy E vary with energy E as the ratio of two Gaussians. This general result, which is valid in the chaotic domain of the spectrum of a finite interacting particle system, is tested for Gamow-Teller strength sums in nuclear (ds) and (fp) shell examples using a interpolating hamiltonian (typical member of a interpolating EGOE(2)) that gradually breaks Wigner's SU(4) symmetry. First results of this study are shown in **Fig. 2.1** and they are obtained using large scale shell model codes. Collaborators in this work are R. Sahu (Berhampur), K. Kar (Calcutta) and J.M.G. Gomez and J. Retmosa (Madrid, Spain).

Similarly the results of a two-spike partitioned EGOE giving bi-modal forms of partial densities are tested in detail in shell model calculations mixing $(ds)^{m=6}$ and $(ds)^{m=4}(fp)^{m=2}$ subspaces (with dimensions 71 and 253 respectively) for angular momentum J = 0 and isospin T = 0. This work is done with D. Majumdar (Calcutta) and R. Haq and R.J. Leclair (Sudbury, Canada).

(V.K.B. Kota)

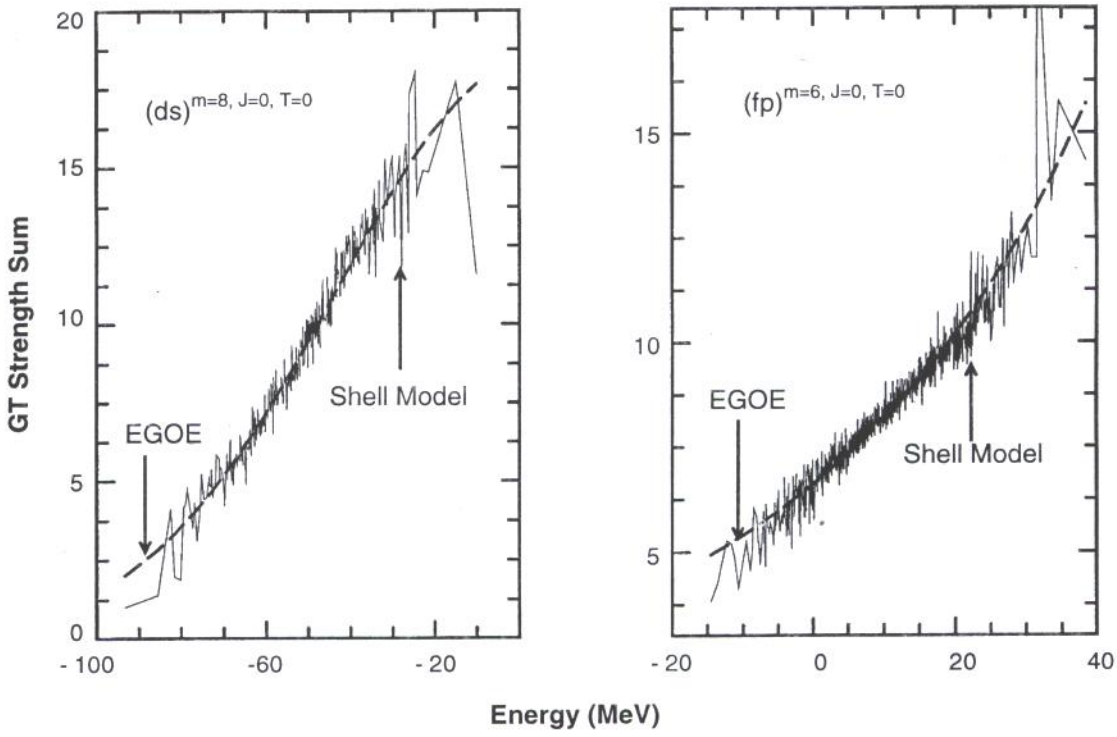

Fig. 2.1. Gamow-Teller (GT) strength sums versus excitation energy (E) for 325 dimensional eight particle (ds) shell space and 814 dimensional six particle (fp)-shell space with angular momentum J = 0 and isospin T = 0. The exact shell model results are compared with the EGOE predictions.

PLASMA PHYSICS

Currents and Field around a Young Stellar Object

A simple model for the generation of current along the magnetic field of a young stellar object, which is threaded into the gas and charged dust of the accretion disc around it, is proposed. The disc is composed of ionized and neutral gas as well as dynamical charged dust. Considering the motion of ions and charged dust, it is shown that the sheared dust-neutral gas velocities can lead to current along the magnetic field direction. This current can be strong enough to generate azimuthal magnetic field which may become large to change the total magnetic field configuration at least near the strong sheared region. The field-aligned flows of particles appear to produce dipolar flows from the stellar object.

(A.C. Das)

Adiabatic Dust-Acoustic Waves with Dust Charge Fluctuations

We study the effect of charge fluctuations on the propagation of adiabatic linear and nonlinear dust-acoustic waves by considering the electrons and ions to be in Boltzmann equilibria, and the dust grains following the fluid equations with full adiabatic equation of state. Linear dust-acoustic waves are damped due to the dust charge fluctuations, and the damping rate decreases with the increase in adiabatic dust pressure. Nonlinear dust-acoustic waves are governed by the set of coupled Boussinesq-like and dust charge perturbation equations. It is shown that for the uni-directional propagation Boussinesq-like equation reduces to usual Korteweg-de Vries (K-dV) equation. At early times, the localized solutions of K-dV equation are damped due to the dust charge perturbations. The soliton amplitude decreases with the increase in the adiabatic dust plasma pressure and increases with

Mach number. Soliton solutions are found only in the supersonic regime.

(S.V. Singh and N.N. Rao)

Coupled Whistler and Ion-Acoustic Mode Propagation in Two-Electron-Temperature Plasmas

The nonlinear coupling between whistler and ion-acoustic modes in a plasma having bi-Maxwellian distributed electrons is considered. For stationary propagation, the coupled waves lead a novel nonlinear structure which has a triple-hump profile for the whistler field intensity. In the critical parameter regime (Δ=3), only super-sonic propagation of the coupled modes is allowed. In other regimes, three integrable cases of the coupled mode propagation have been identified. This work was carried out in collaboration with P.K. Shukla.

(N.N. Rao)

Localized Nonlinear Structures of Intense Electromagnetic Waves in Two-Electron-Temperature Electron-Positron-Ion Plasmas

Nonlinear propagation of intense electromagnetic waves in a hot electron-positron relativistic plasma containing a small fraction of cold electron-ion component has been investigated by deriving a generalized Schrodinger-Boussinesq system of coupled equations. The latter includes self-nonlinearity in the electromagnetic field amplitude due to the relativistic effects, and describes the coupling between the high-frequency electromagnetic wave and low-frequency electron-acoustic wave arising from the cold plasma component. For stationary propagation of finite amplitude waves, only super-sonic solitons are found to exist while for quasi-neutral, linear low-frequency plasma response both sub- as well as super-sonic solitons can occur. Relevance of these results to astrophysical situations is pointed out. This work was carried out in collaboration with N.L. Shatashvili.

(N.N. Rao)

Instability of Contra-Streaming Dust Beams in Dusty Plasmas

It is shown that contra-streaming dust and ion beams in dusty plasmas are unstable against dust-acoustic and dust ion-acoustic disturbances, respectively. Analytical expressions for the growth rates and thresholds are presented. The relevance of our investigation to cometary plasmas has been pointed out. This work was carried out in collaboration with P.K. Shukla.

(N.N. Rao)

Nonlinearly Coupled Langmuir and Dust-Acoustic Waves in a Dusty Plasma

The nonlinear propagation of coupled Langmuir and dust-acoustic waves in a dusty plasma has been considered. The coupled mode propagation is described by a Schrödinger-Boussinesq system, which reduces to the Schrödinger-K-dV system for an uni-directional wave propagation. For the stationary propagation, the waves are governed by a generic Hamiltonian which is integrable in sub- as well as super-sonic regimes of the Mach number. Depending on the parameter regimes, exact analytical solutions for the coupled waves having single, double and triple-hump structures for the Langmuir field intensity have been obtained. The exact governing equations for large amplitude waves have also been derived and solved approximately. The existence of large amplitude solutions in the quasi-neutral limit are discussed. This work was carried out in collaboration with P.K. Shukla.

(S.V. Singh and N.N. Rao)

Fluid Equations for Dusty Plasmas with Grain Charge and Mass Fluctuations in Interaction with Neutral Dust

A self-consistent set of fluid equations are derived as appropriate moments of the Boltzmann equation for the charged dust component generalized to include mass and charge of the dust as variables, with source/sink terms to describe the charging of the dust grains. As in most astrophysical scenarios, the neutral dust is also present, the fluid equations for the neutral component in interaction

with dust plasma are also obtained. These equations together constitute a general description for the dusty plasma where both masses and charges vary over the particles. New, interesting terms appear in these equations because of these generalizations, and equations offer possibilities into investigations of new and hitherto unexplored areas of dust plasma dynamics.

(R.K. Varma)

Modification of Dust Plasma Frequency and Landau Damping due to Grain Charge Fluctuations

Starting from a Boltzmann equation generalized to include grain charge variation, a kinetic dispersion relation is obtained for the dust plasma oscillations in an unmagnetized dust plasma. It has been shown that dust plasma frequency suffers a small decrease due to the grain charge fluctuations. This is in contrast to the earlier conclusions that the grain charge fluctuations only cause the damping of the modes. Also, surprisingly the Landau damping is found to decrease, due to these charge fluctuation effects.

(R.K. Varma)

It is well known that in classical mechanics deceptively simple equations of motion lead to very complex motion in phase space. This kind of behaviour is characteristic of systems in which interaction is nonlinear and in general solutions of equations of motion require the use of the computer. A key element in the progress is the visual display of the solutions on high resolution computer graphic systems which enable the investigator to identify and explore patterns in complex nonlinear phenomena. A short account of investigations on both quantum and classical systems together with work on pattern recognition problems is given below:

Chaos in 1D Square Well

Classical dynamics of a particle confined in 1D infinite square well potential subjected to time periodic electromagnetic pulses has been systematically studied. In general, dynamics of the particle is chaotic. It is, however, seen that this system displays a variety of dynamics. In particular, smooth and abrupt transition to chaos has been observed for different parametric regimes. Abrupt transition to chaos, for weak external field strength, has been attributed to the competing length scales invloved in the system, that is, the width of the well and wavelength of the external pulsed field, leading to large scale diffusion. This kind of transition can also give rise to highly inhomegeneous phase space in some cases. In such cases diffusion may be suppressed, even in the absence of KAM tori, due to the existence of chain of regular islands in the phase space (**Fig.3.1**). The presence of accelerator modes, that is, orbits having constant acceleration at each time step, and their role in altering the otherwise normal diffusion to anomalous diffusion has also been investigated.

The quantum counterpart of this classical system is also under study. A generic quantum system does not show long time diffusion while the corresponding classical system has diffusive nature. Quantum version of the accelerator modes are carried out with initial gaussian wavepacket placed on the modes. In appropriate semiclassical limit remarkable classical-quantum correspondence is seen.

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

Chaotic Quantum Systems with Three Degrees of Freedom

The work on calculating the eigenvalues and eigenfunctions of a Hamiltonian system with three degrees of freedom is continuing. In such a system the resulting Hamiltonian matrix has a very large dimensionality which gives rise to severe computational problems. We are developing methods to efficiently diagonalize large matrices. This work is being done with M. S. Santhanam.

(S. A. Pandit, A. Lakshminarayan and V.B.Sheorey)

Parameter Estimation via Synchronization

It is shown that given a chaotic signal of a scalar quantity, a combination of synchronization and adaptive control can be used to estimate some parameters of the underlying dynamical system. In some cases three or four parameters can be determined. The method minimises the synchronization error dynamically. The accuracy of parameter estimation depends on the length of the time series available and improves as the duration of the available time series increases. The method may be useful in accurate determination of some parameters and also in determining the form of unknown perturbations. This work was done in collaboration with A. Maybhate.

(R. E. Amritkar)

Nature of Transitions in Augmented Discrete Nonlinear Schrödinger Equations

The nature of the transitions between free and self-trapping states occurring in systems described by augmented forms of the discrete nonlinear Schrödinger equation are investigated. These arise from an interaction between a moving quasiparticle (such as an electron or an exciton) and lattice vibrations when the effects of nonlinearities in interaction potential and restoring force are included. Analytic conditions for the stability of the free state and the crossover between first and second order transitions are derived. Depending on the type of nonlinearity, it is possible to have both first and second order transitions. This work was done in collaboration with V.M. Kenkre.

(R. E. Amritkar)

and independent of any external parameters such as topology of the underlying space of the network. It is shown that the far edges are mainly responsible for the fast spreading of any quantity in a network such as an epidemic. We show that the far edges can be used to control the spread of an epidemic. We also suggest models to control the spread of an epidemic and for better product advertisement using the far edges.

(S.A. Pandit and R. E. Amritkar)

Multivariate Time Series Modelling in a Connectionist Approach

Multivariate models in the framework of artificial neural network have been constructed for systems where time series data of several variables is known. The models have been tested with the computer generated data of the Lorenz equations and also the Henon map. They not only give an excellent fit to the data (in the training set) but also generate very good short term (iterated single step) predictions. Thus, the models have successfully captured the multivariate dynamics. The study of linear and nonlinear correlations amongst the variables of the models is able to throw some light on theoretical questions related to multivariate 'embedding' and removal of redundancy in the embedding.

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

Black Hole Evolution

We have numerically studied the evolution of a Schwarzschild black hole embedded in a gravitational wave background. The modes of oscillation of the system and the gravitational waves produced have been determined. The system has been used to compare the standard Arnowit-Deser-Misner formulation with the newer Bona-Masso formulation. A general purpose numerical relativity code, CACTUS, is being employed for this study. CACTUS has been successfully implemented at PRL. This project is part of a collaboration with the Albert Einstein Institute, Germany.

(Sai Iyer)

Evolution of Stars

The nonlinear (General Relativistic) evolution of stars described by various equations of state is being studied numerically. The study is at present limited to spherically symmetric configurations. Apart from its importance for the investigation of gravitational collapse and the cosmic censorship hypothesis, this study will provide an invaluable test-bed for more general codes dealing with non-spherical configurations.

The accuracy of successively higher orders of post-Newtonian approximation in the study of equilibrium configurations of compact stars is being studied using the Tolman-Oppenheimer-Volkoff equations and independently using numerical relativity. The effect of these approximations on the stability of the systems is also under investigation. This work is in collaboration with Anshu Gupta.

(A. Gopakumar and Sai Iyer)

Stationary Phase Approximation

Traditionally the stationary phase approximation (SPA) has been used to compute the waveform in the frequency domain for inspiralling binaries. We have observed that SPA breaks down at the 2.5 post-Newtonian order and have computed a valid expression for the waveform at that order. Currently, we are numerically checking the validity of this expression.

(A. Gopakumar and Sai Iyer)

Identification of Supergranules

The GONG experiment is a land based network of instruments and produces Dopplergrams of the Sun's disk every minute continuously with a chain of six instrument placed around the globe. The Dopplergrams (vda images) recorded by the GONG instrument were analysed with the goal of evolving computational techniques to recognise supergranulations without human aid so that large number of Dopplergrams can be analysed and supergranualations can be studied for various features such physical characteristics, scale sizes, life times, distribution, localisation etc.

The detrended Dopplergram images are subjected to wavelet decomposition using "a trous" algorithm into various scales and images with suitable scale sizes are used for further processing by conventional as well as neural network techniques to identify supergranulations and find its temporal and spatial properties. Several programmes and scripts have been written to process large number of vda images from multiple stations.

(S. N. Pradhan)

Web Applications

The presence of large number of high end workstations present on a network offers the opportunity to do distributed processing with platform independent language such as Java . We have initiated development of Distributed Image Processing System (DIPS) using Java Remote Method Invocation (RMI) technology.

(S. N. Pradhan)

Pattern Recognition and Neural Network

Recognition of hand written character is a very challenging problem in pattern recognition. As a beginning the problem of recognition of the constrained hand written character has been taken up. The block constrained characters are used as input to a NN classifier and further subjected to supervised competitive learning . The network trained for a small sample size of 20 set of uppercase characters gave an 85% success on the test data. The present process of preparing input patterns from scanned image involves manual interaction. Once this process is automated large data samples with test samples can be used to expand the scope of pattern recognition to a larger character set and sample size.

(S. N. Pradhan)

Large Databases

In collaboration with Planetary Atmospheric Division, mining of INDOEX (Indian Ocean Experiment) archive databases has been taken up. Databases of interest have been identified, downloaded and converted into suitable format for modelling work.

(J. J. Trivedi)

The research interests of this division continues to be the quantum and nonlinear aspects of light and its interaction with matter. Some of the research activities of the past year are as follows:

Vacuum Induced Potentials

It is known that optical potentials can be created by the applications of off-resonant electromagnetic fields. The resulting ac stark shifts of the energy levels are like a potential which the moving atom will experience. Such potentials have been extensively studied. Optical lattices are manifestations of such potentials. We have been examining the passage of ultra-cold atoms through cavities. We find that the interaction with the *vacuum* of the cavity can produce potentials from which cold atoms can be reflected or transmitted. We have undertaken a systematic study of such potentials. A remarkable consequence of such potentials is the coupling between two, otherwise uncoupled, cavities.

(R. Arun and G. S. Agarwal)

Finite Beam Curvature Related Patterns in a Saturable Medium

In a numerical study of Gaussian beam propagation through a saturating non-linear medium, we have shown how the finite curvature of the input beam can generate very different kinds of patterns which depend on the convergent/divergent nature of the beam and on the focussing/defocussing characteristics of the medium (**Fig.4.1**) . The ellipticity of the beam is shown to give rise to optical vortices, which multiply as the nonlinearity of the medium increases. This work was done in collaboration with R. Kapoor, Centre for Advanced Technology, Indore.

(G. S. Agarwal)

Reconstruction of an Entangled State in Cavity QED

In recent times, the subject of state reconstruction has become a major field of study in quantum optics. Reconstruction of entangled states gains an added importance because entanglement is at the heart of current developments in quantum information theory, teleportation,

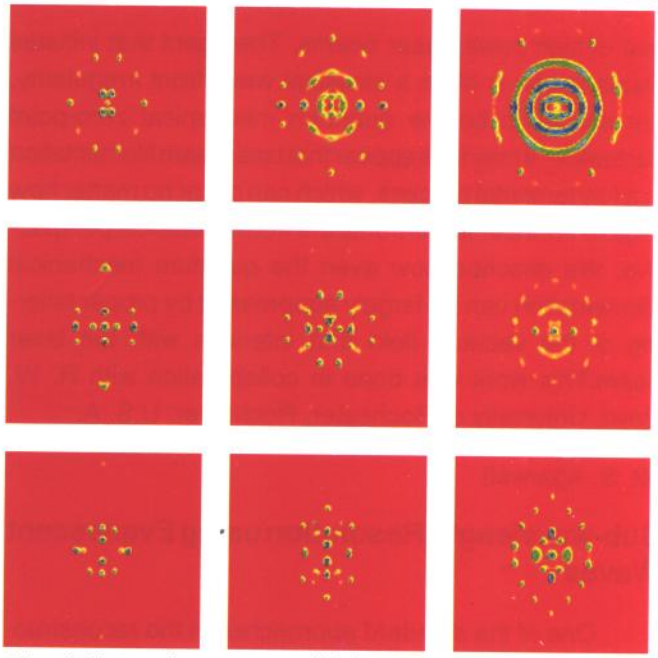

Fig. 4.1 Intensity patterns of light produced by a converging elliptic Gaussian beam as it propagates through a focussing nonlinear medium.

computing and cryptography. Much of the earlier reconstruction schemes were for single mode fields. We suggest a scheme to reconstruct a two-mode entangled state in cavity QED by using the interaction of a V-configuration three-level atom and by driving the cavity field. After the atomic interaction with the cavity fields, the probability of the atom being in its initial ground state is found to be directly related to the two-mode Wigner characteristic function. The Wigner function and the density matrix elements can be obtained for the two-mode entangled field by simple transformations. The two entangled modes can be prepared in one cavity or in two spatially separated cavities. We considered both these cases. This work was done in collaboration with M. S. Kim, Sogang University, Seoul, Korea.

(G. S. Agarwal)

Preventing Laser Beam Filamentation through use of the Squeezed Vacuum

The tendency of a laser beam to break up into a filamentary structure as it passes through a nonlinear optical medium is a serius problem that can hamper the

use of high power laser beams. The agent that initiates filamentation is often a classical wave-front irregularity, but can even be the quantum mechanical zero-point fluctuation. It may thus appear that laser beam filamentation is a fundamental process, which can occur no matter how regular the laser wave-fronts are from a classical perspective. We describe how even the quantum mechanical filamentation can be largely suppressed by proper tailoring of the vacuum field that interacts with the laser beam.This work was done in collaboration with R. W. Boyd, University of Rochester, Rochester, U.S. A.

(G. S. Agarwal)

Sub-wavelength Resolution using Evanescent Waves

One of the standard approaches in the reconstruction of a scattering object is to examine the scattering field in the first Born approximation assuming that the scattered potential $V(\mathbf{r})$ is weak. In such a case, the scattered field in the direction $\mathbf{k}$ in the far zone is proportional to the Fourier component $\mathbf{k} - \mathbf{k}_0$ of the potential, where $\mathbf{k}_0$ is the Fourier component in the incident plane wave. Both $\mathbf{k}$ and $\mathbf{k}_0$ are subject to the condition $|\mathbf{k}| - |\mathbf{k}_0| = \omega / c$, where ω is the frequency of the incident wave. The potential is static. Thus one concludes that the study of the scattered field can at best give all the Fourier components of $V(\mathbf{r})$ lying inside the so-called Ewald sphere characterized by $|\mathbf{k} - \mathbf{k}_0| \leq 2\omega / c$. Thus, it appears that structures smaller than a wavelength cannot be resolved.

For the determination of sub-wavelength structures, we use techniques of near-field optics, in particular, an earlier theory due to Wolf. We present a generalization of Wolf's theory by including evanescent waves both in the incident and scattering fields. This inclusion yields a lot more information on the scattered potential. In fact, in some cases, we can get a complete potential by combining this with the symmetry property of the potential. We also present a framework for the study of sub-wavelength surface structure using radiation from an excited dipole near such a structure as the probe.

(G. S. Agarwal)

Mesoscopic Superpositions of States: Approach to Classicality and Diagonalization in a Coherent State Basis

Mesoscopic superpositions of coherent states have been the subject of extensive studies because of their unusual interference characteristics and because of their relevance to the quantum measurement problem. These states are also known to be extremely sensitive to environmental interactions. The interference terms disappear fast and a kind of diagonalization takes place. The diagonalization is itself sensitive to the nature of the interaction with environment.

We show how the presence of a gain medium in a cavity can lead to classicality and diagonalization in coherent state basis in contrast to the standard model of decoherence.

(G. S. Agarwal)

Cavity-induced Coherence Effects in Spontaneous Emission from Preselection of Polarization

Spontaneous emission can create coherences in a multilevel atom having closely lying levels, subject to the condition that the atomic dipole matrix elements are non-orthogonal. This condition, which is rarely met in atomic systems, arises from the fact that spontaneous emission occurs in two orthogonal modes of polarization. We report the possibility of bypassing this condition and thereby creating coherences by letting the atom with orthogonal dipoles interact with the vacuum of a pre-selected polarized cavity mode rather than the free space vacuum. It is shown that this cavity-induced coherence leads to quantum beat structure in the level populations.

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

Momentum Induced Effects in Wave Packet Dynamics in an Infinite Square Well Potential

The infinite square well potential is an ideal theoretical model to illustrate the phenomenon of quantum revivals since simple analytical forms for the eigenvalues and eigenfunctions make it easy to analyse the dynamics of any initial state and to study revival patterns. Further

insight into the origin of the interference effects which lead to the 'canals and ridges' structure of the 'quantum carpets' (space-time density plots) is obtained by looking at the time evolved Gaussian wavepacket at one-fourth the revival time. We show in a simple way how the initial momentum of the wavepacket enhances interference terms and affects revival patterns. The signature of these momentum induced effects can be seen in the autocorrelation function and in the space-time density plots.

(Anu Venugopalan)

Gain From Cross-Talk Among Optical Transition

In a multilevel atom with two closely spaced energy levels, a single field can pump more than one transition. We present the effects of such common coupling on probe response in a driven system with closely spaced ground levels. It is shown that cross-talk among optical transitions can result in new interference effects. As a result, a probe field can experience significant gain without requiring population inversion. Furthermore, it is shown that the gain and absorption of the probe field depends strongly on the relative polarizations of the pump and probe fields.

(S. Menon and G. S. Agarwal)

Probing The Vacuum-Induced-Coherence

The vacuum of the electromagnetic field is known to give rise to several types of very interesting coherence effects. For example, in a single multilevel atom, it can generate coherent superpositions between energy levels. This happens when spontaneously emitted photons along one transition strongly couple with an adjacent transition. The coherence (superposition) thus created, has been a topic of intense activity in recent times. In a V-system (two closely spaced excited levels of same parity, dipole-coupled to a common ground level), the vacuum-induced-coherence (VIC) among the two excited states can be easily detected because it significantly modifies the spontaneous emission spectrum. Unfortunately, the same does not happen with a Λ- system. We answer this question of monitoring VIC in a Λ -system. We show that the elusive VIC in a Λ -system can be detected through probe absorption. We explain the origin of VIC and present analytical and numerical results for the modulated absorption, the cosine and sine components of which display different types of behaviour.

(S. Menon and G. S. Agarwal)

Self-focussing and Optical Limiting Studies in Nonlinear Crystals using Z-scan Technique

When a single light beam propagates in a photorefractive (PR) material, it induces a change in the refractive index resulting in focussing or defocussing of the beam itself. If the light-induced focussing exactly compensates the diffraction of the beam, an invariant intensity profile, called the spatial soliton, is formed along the beam propagation direction. Spatial solitons have important applications in optical switching and routing. PR materials show self-focussing at very low optical powers which makes them promising candidates for soliton formation. To that end, we have used Z-scan technique to investigate experimentally the self-focussing in a photorefractive BSO crystal for different light intensities, wavelength, external electric field and additional homogeneous illuminations. The results are encouraging for the observation of photorefractive spatial solitons in BSO. This work was carried out in collaboration with Dr. D. Narayana Rao, University of Hyderabad.

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

Optical Vortices

Optical vortices are singularities in the electric field and are produced when the magnitude of the electric field vanishes at certain locations, called defects of the wave field. Invariance properties of optical vortices may find many applications in areas of optical interconnections and similar technologies. Keeping this in view, work has been started to produce optical vortices and study their propagation in the laboratory using conversion of Hermite Gaussian (HG) beam to Laguerre Gaussian (LG) beam which contains an optical vortex.

We were successful in producing a LG_{01} beam from the HG_{00} beam of a He-Ne laser by using a computer generated hologram. Also LG_{01} mode was converted back to HG_{00} mode using a cylindrical lens mode con-

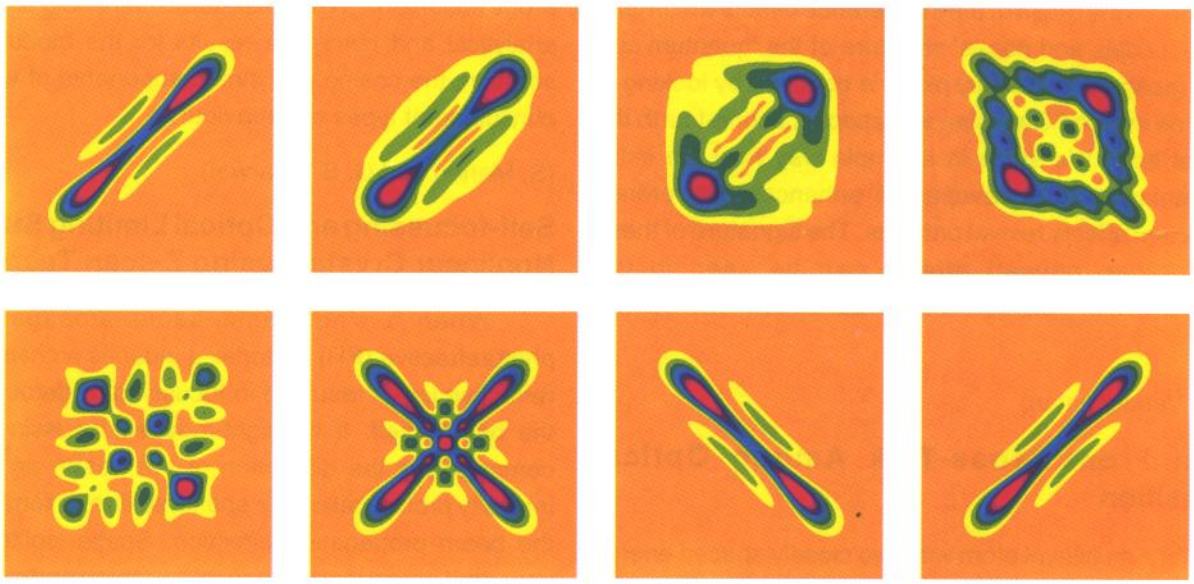

Fig.4.2 Time evolution of the probability density for pair coherent states under the action of a nonlinear Hamiltonian. Each frame corresponds to a different time instant T:Top row (left to right T=0.0,0.03, 0.06, 0.09; bottom row (left to right) T=1/4, 1/2, 1, 2. Note how the initial coherent structure is lost quickly, but is regained later on to from a Schrödinger cat at T=1/2 and eventually to experience full revival at T=2.

verter designed in the laboratory. This work was carried out under the guidance of Prof. L. Allen, University of St. Andrews, UK during his visi to PRL. We are also grateful to him for providing the hologram.

(R. P. Singh)

Theory of Beam Splitting and Regeneration in a Multi-mode Rectangular Waveguide

We present an analytical study of how an arbitrary input beam splits, recombines and reproduces itself inside a multi-mode rectangular waveguide. We first provide an analytic solution for a propagating symmetic field and present exact results for its phase values at the split field points. This phase information will be quite useful in calculating design parameters for splitters, mixers, recombiners, signal routers and Mach-Zehnder type interferometers. Next, we extend our work to consider antisymmetric input beams and finally, more genaral input beams, in particular, laterally offset input beams. This work was done in collaboration with A. R. Davies, University of London and R. M. Jenkins, DERA, Malvern, U. K.

(J. Banerji)

Revival and Fractional Revival in the Quantum Dynamics of SU(1,1) Coherent States

We have used a generic two-mode Hamiltonian with two associated time scales to study the evolution of generalized SU(1,1) coherent states, in particular, the pair and Perelomov coherent states, which have been realized in many systems such as radiation fields, trapped ions and phonons. We have found that their dynamics does not depend on the ratio of these time scales but is instead determined crucially by the difference in photon numbers of the two modes. This is in stark contrast with the previously studied harmonic oscilator coherent states and can be attributed to the different nature of the underlying algebra. We provide analytical results for their revival and fractional revival and demonstrate the formation of Schrödinger cats (**Fig. 4.2**). The results are extremely sensitive to the parameters that characterize the SU(1,1,) coherent states.

(J. Banerji and G. S. Agarwal)

The research programmes of the division encompass three major disciplines namely, middle atmospheric physics, upper atmospheric physics, including the planetary and cometary atmospheric studies, and laboratory astrophysics. Scientific results from the above research activities are given in the following sections.

Middle Atmosphere

Latitude Gradient in Aerosol Characteristics Found over the Indian Ocean

As part of the Indian Ocean Experiment (INDOEX), a total of four ship cruises have been conducted over the Indian Ocean in the months of January to March from 1996 to 1999, the last one being the ORV Sagar Kanya cruise from 20 January to 12 March 1999. In all these cruises, coordinated measurements of aerosols, surface reaching solar flux and trace gases were made. One of the important results is on the latitude gradient obtained in the aerosol size distribution and the aerosol spectral optical depth. Independent measurements of the aerosol size distribution and the spectral optical depth made during the INDOEX cruises over the Indian Ocean reveal that the sub-micron size particles produced from gas-to-particle conversion mechanism, exhibit systematic latitude gradient and are responsible for the latitude gradient observed in the aerosol optical depth in the mid visible and lower wavelengths (**Fig. 5.1**). The coarse particles, which are mainly mineral particles derived from the sand, are comparatively not transported into long distances over ocean surfaces because of their heavy mass. The other coarse particles e.g. the sea-salt particles produced from sea spray are not expected to show any appreciable latitude gradient. The consequence of this study is that, we now have better handle on the type of aerosols we should consider in making model studies on the impact of aerosols in global and regional level climate change studies.

(A. Jayaraman)

Atmospheric Structure Revealed by the Nd:YAG Backscatter Lidar at Mt. Abu

The Nd:YAG backscatter lidar at Mount Abu is now being operated continuously in the Rayleigh, Mie and Raman modes for obtaining the vertical structure of the atmosphere in terms of atmospheric density and temperature and to examine their long term changes. In the Rayleigh scattering mode, the backscattered radiation from air molecules in the 30 to 80 km region is measured with an altitude resolution of 96 m. Using the Rayleigh backscattering cross-section, the measured backscattered intensity is converted into number density profile. Using the hydrostatic equation and perfect gas law, the temperature profile is derived. However, below about 30 km, the backscattered radiation is a sum of radiation scattered by air molecules and aerosols. In order to discriminate the two components, measurements are made in the elastic and inelastic scattering modes. In the inelastic scattering mode, the Raman scattered radiation from the nitrogen molecules is measured to derive the air density and hence the temperature profile in the lower atmosphere. From the

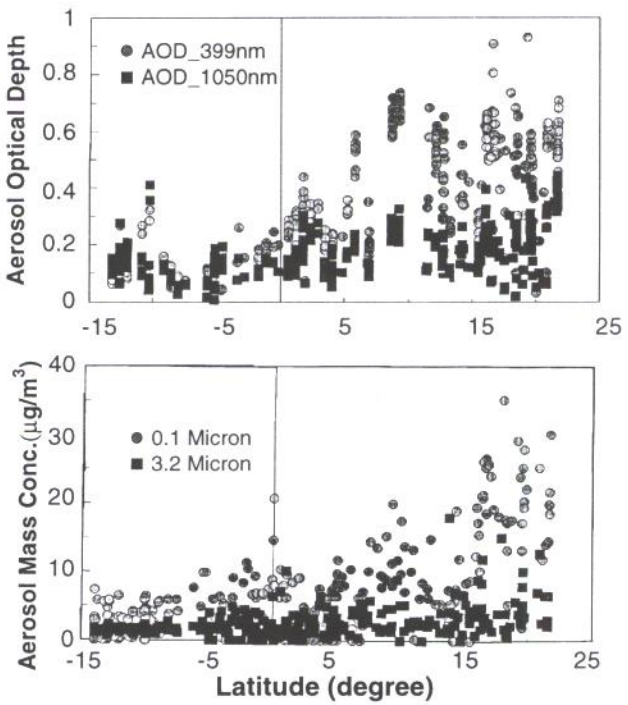

Fig. 5.1 Composite plots of columnar aerosol optical depth (top) and aerosol mass concentration (bottom) measured in situ *over the Indian Ocean during the INDOEX ORV Sagar Kanya cruises conducted in the months of January to March during the years 1996 to 1998. More prominent latitude gradient is seen in the sub-micron (0.1μm) particle size compared to bigger particles (3.2 μm) which is responsible for the latitude gradient seen in the aerosol optical depth at 399 nm.*

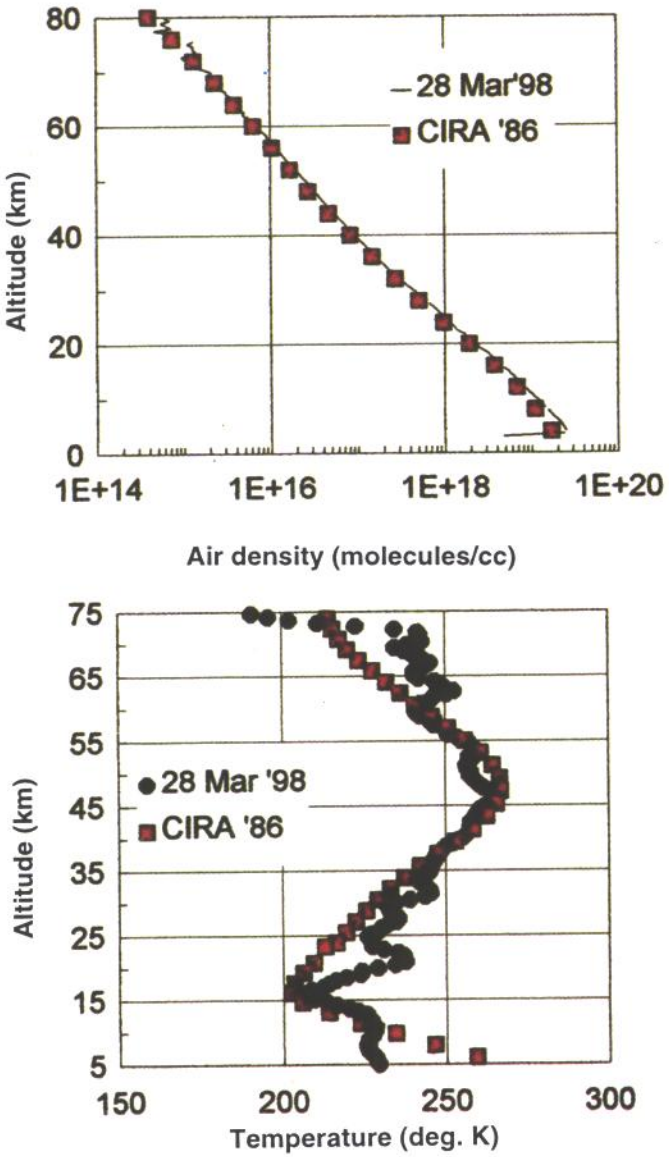

Fig. 5.2 Three Rayleigh scattering data profiles and two Raman scattering data profiles, all made within one hour of lidar operation on a typical day of March 28, 1998 are averaged to obtain the density (top) and temperature (bottom) profiles. For comparison CIRA 1986 model profiles are also shown.

elastic scattering measurements, the contribution due to air molecules is removed and the aerosol backscattering profile is obtained. Thus by combining the Rayleigh, Mie and Raman scattering observations, vertical profiles of neutral air density in the 5 to 80 km, and aerosol concentration in the 5 to 30 km altitude regions are obtained successfully. **Fig. 5.2** shows the typical results from the lidar operation made on 28 March 1998.

(A. Jayaraman, H. Chandra, Y.B. Acharya, S. Sharma and J.T.Vinchhi)

Vertical Distribution of Trace Gases

A cryogenic air sampler was flown aboard a balloon from Hyderabad on April 18, 1998 at 0355 hrs. The balloon reached the ceiling altitude of 36.7 km. Fifteen air samples were collected during the ascent and apex valve controlled descent of the balloon spaced between 6 and 36.7 km. The collected air samples are being analyzed at PRL using gas chromatographic techniques. Some of the gases like CH_4, CO, SF_6, N_2O, CFC-11, CFC-12 etc. have already been measured. The preliminary results show very small growth rates for CFC-11 and CFC-12 when compared with the results of the balloon flight conducted in 1994. However, SF_6 is found to increase at the growth rate of 8%/year during this period. Methane and nitrous oxide (N_2O) do not show any discernible change beyond the analytical errors in their mixing ratios. Measurements for other gases are being made.

(S. Venkataramani, Duli Chand and Shyam Lal)

2D Photochemical Model for the Study of Atmospheric Chemistry

A two dimensional (2D) photochemical transport model has been used to assist field observations from Hyderabad in an attempt to identify key processes in the troposphere and stratosphere. The model developed at Max Plank Institute of Chemistry (MPIC), Germany, was appropriately modified to run on IBM RS6000 at PRL. The model was tested by comparing the results with data from our balloon measurements and UARS satellite.

We performed a 20 year simulation after incorporation of SF_6 as a new species in the model. This anthropogenic trace gas is a good dynamical tracer of the atmospheric circulation due to its long lifetime and rapid growth rate. When estimates of the global SF_6 emission rates were geographically distributed according to electric power production in the model, the meridional distribution compared well with observations, compared to distribution

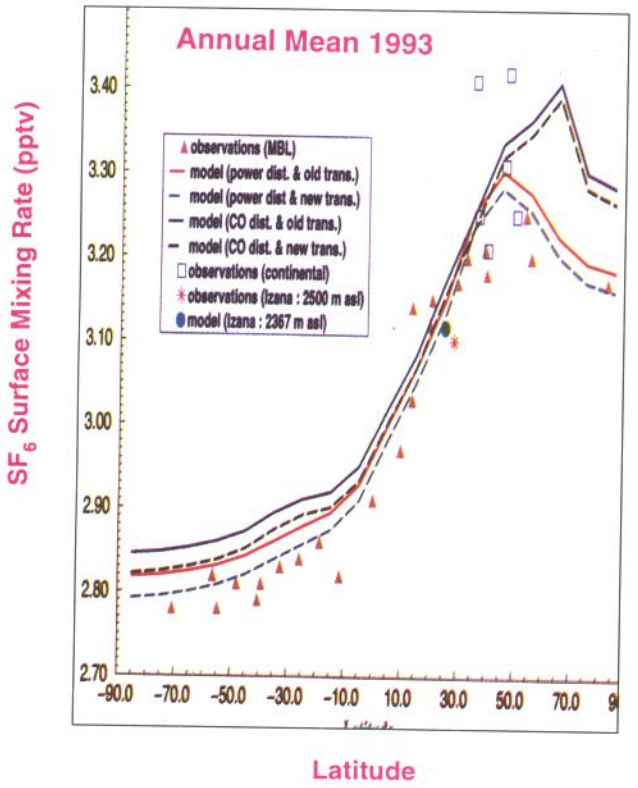

Fig. 5.3 Latitudinal surface mixing ratio of SF_6 as modelled by the 2D, PRL-MPIC model for different transports and distributions.

when carbon monoxide was used in the model (**Fig. 5.3**). We also studied the seasonal behavior and vertical profiles for various latitudes. The model produces the observed gross features pretty well, but cannot reproduce the weak vertical gradient observed above 25 km over Hyderabad. This and other issues are being investigated to achieve a better formulation of dynamics in our model.

(Varun Sheel and Shyam Lal)

Measurements of Ozone and Related Species Over the Indian Ocean

Intensive Field Phase (IFP) experiment of INDOEX was conducted during January-March 1999 covering the latitude range from 16°N to 20°S and also for the first time, two horizontal lags, one along the ITCZ and other in the northern Arabian Sea. These measurements also overlapped with the measurements made on the American ship and satellite measurements as a part of the international INDOEX programme. Apart from regular measurements of O_3, NO, CO and CH_4, measurements of solar UV-B were also made during this cruise, to estimate its attenuation by ozone and other species. Analysis of these results is in progress.

Measurements made during the 1998 INDOEX-FFP show the effect of ITCZ. Higher levels of ozone and other gases have been observed towards the north of ITCZ due to the pollutants from the continents and clean and pristine air to the south of ITCZ. It was found that the movement of ITCZ can cause transport of high ozone (more than 80% of background levels) in the clean Indian Ocean. Very low levels of ozone (~ 5 ppbv) were also observed near 10-15°S during IFP 99. This indicates that it is not a sporadic phenomenon but is due to catalytic loss of ozone in the low NO environment.

A comparison of surface ozone measurements with the total tropospheric ozone (derived from vertical ozone distribution obtained from ICPA, Julich, Germany) shows good agreements in latitudinal variation except near coastal regions. This suggests that, surface level ozone is an indication of tropospheric ozone levels over the Indian Ocean.

(Manish Naja, K.S. Modh and Shyam Lal)

Measurement of Iodine Oxide (IO)

It is now known that though bromine, iodine and fluorine compounds destroy ozone more vigorously than chlorine compounds but nothing is known about the distribution of these species in the low latitude region. We are attempting to measure the column density of iodine oxide at Ahmedabad by monitoring solar radiation at 426.9 nm absorbed by IO using the 1200 G/inch grating spectrograph with 512 diode array detector. The observations are taken during twilight, morning and evening time in the range of 423.62 to 442.13 nm. The spectra thus obtained are contaminated by Fraunhofer lines which were removed by dividing by a noon time spectrum. Some very preliminary analysis has been done and the value of slant column density of IO comes out to be of the order of 10^{14} cm^{-2}.

(S. Banerjee, D.K. Chakrabarty, S.R. Das and N.C. Shah)

Atmospheric Oscillation during Solar Eclipse

Ozone observations were carried out during the solar eclipse on 24 October 1995 by various groups at different places. We have collated these results. Since the life time of ozone is much more than the duration of the eclipse, a variation of this species during eclipse was not expected. But we found a variation which was not proportional to the visible portion of the solar disk. Since ozone absorbs UV radiations, a fluctuation in ozone column should cause fluctuation in the UV intensity measured on ground during eclipse. But observational results do not corroborate this fact. Also variation in ozone was not found proportional to the variation of NO_2 density. These variations are not explainable by the presently known conventional photochemical and dynamical processes which are likely to occur during the eclipse. These variations are due to some aspect of planetary hydrodynamical theory which needs further investigation.

(D.K. Chakrabarty, S.K. Peshin and S.K. Srivastav)

Ozone at Different Altitudes Over the Years

We have examined about forty five years of Umkehr ozone data at six stations of India. The stations are Kodaikanal, Ahmedabad, Varanasi, Pune, New Delhi and Srinagar. Our analysis shows that at all the stations at lower troposphere, there is an increasing trend of ozone and in the region where the concentration of ozone is maximum, there is a decreasing trend of ozone. At other altitudes, trends are different at different places. This trend of ozone at lower troposphere and at ozone maximum region is found to be consistent with the global warming trend.

(K.V. Pandya, N.C. Shah and D.K. Chakrabarty)

Polar D-region Model for Summer Noontime Condition

Theoretical model of D-region ions for the Antarctic and Arctic summer condition has been prepared using an ion-chemical scheme in which 65 reactions have been considered. It is found that $HCO_3^-.(H_2O)_2$ and $HCO_3^-.(H_2O)_3$ are predominant negative ions in the Antarctic and $HCO_3^-.(H_2O)_3$ and $HCO_3^-.(H_2O)_4$ are predominant negative ions in the Arctic. These ions are present upto about 85 km. In the positive ion side, the predominant ions are $H^+.(H_2O)_5$ and $H^+.(H_2O)_6$ in the Antarctic and $H^+.(H_2O)_6$ and $H^+.(H_2O)_7$ in the Arctic. The disappearance level of these ions at Antarctic is about 2 km lower than that at Arctic.

(D.K. Chakrabarty)

Short Term Oscillations in Mesosphere

Long sequences of the hourly average zonal and meridional wind components at mesospheric altitudes obtained by MF spaced antenna radars located at Davis (69° S, 78° E), Buckland Park (34° S, 138° E) and Christmas island (2° N, 157° W) are spectrally analysed to study the short period oscillations. Apart from the tidal components and harmonics, there are oscillations with periods ranging between 4 and 11 hours. Moving power spectra are obtained to study the seasonal dependence of the short period oscillations. The wave activity is strongest during J-solstices and weakest during equinoxes at each of the locations. This work was done in collaboration with Prof. R A Vincent and S Kovalam of Adelaide University.

(H. Chandra)

Observations of Mesosphere by MST Radar

The radar returns from the lower regions of the atmosphere are typically continuous in time and altitude, those from the mesosphere are only sporadically returned from discrete layers with narrow vertical extents; moreover, the signal strengths are much weaker. An evaluation has been made of the radar signal processing techniques in order to ensure that the most reliable geophysical interpretations can be made from the limited data available. In particular, attention has been focussed on the most appropriate method of identifying the signal portions of the radar Doppler power spectra. The effects of first smoothing the data with 3 and 5 bin running means lead to much more appropriate estimates of the Doppler shift.

(D. A. Hooper, H. Chandra and Som Sharma)

Upper Atmosphere

First Experimental Confirmation of Image Striation Theory in the F-Region Valley

Simultaneous measurements of electron density and electric fields were made over SHAR on October 4, 1988 using a rocket-borne Langmuir probe and electric field double probes during a fully developed spread F epoch. These measurements showed the presence of electron density and electric field irregularities in 165-178 km region, which falls in the F-region valley. Earlier electron density measurements over SHAR observed a smooth profile of electron density. Spectral analysis of both electron density and electric field perturbations, in the 165-178 km region, showed the presence of a spectral peak at 2 km scalesize. In view of the fact that these irregularities cannot be produced locally, by any of the presently known mechanisms, existence of these irregularities has been explained in terms of the image striation theory. The image striation theory predicted a scalesize dependent effective diffusion process in the F-region, which dominates over the classical cross-field diffusion at kilometre scale sizes. The present observation of spectral peak at 2 km scalesize, in the electron density and electric field spectra, simultaneously (at 172 km), therefore, is the first experimental confirmation of the image striation theory through electric field measurements. Earlier confirmation of the theory was based on the electron density measurements alone.

(H.S.S.Sinha, Shikha Raizada and R.N. Misra)

Evidence of a Sheared Flow of Vertical Current at SHAR during a Strong Spread F

In-situ measurements of electron density, vertical and horizontal electric field perturbations (n_e, E'_V and E'_H) over SHAR during a strong spread F event showed the simultaneous presence of irregularities in the F-region valley, below the F-region base and near the F-peak. A correlation analysis of n_e, E'_V and E'_H perturbations (over a vertical interval of 10 km) for all the three regions indicated that i. the correlation coefficient between n_e and E'_V is a very sensitive function of the amplitude of irregularities in the intermediate scale (~ 0.2-8.0 km) and ii. n_e and E'_V are highly correlated at strong irregularity amplitude. Correlation coefficients of -0.83, +0.90 and -0.92 at 175 km, 245 km and 305 km, respectively, illustrate this point. It is well known that a westward plasma flow occurs below the F-peak, which means that the current flow is downwards. If the vertical neutral wind is small enough, this downward current could, by analogy, produce a positive correlation between the electron density and electric field fluctuations.Thus, the present observations suggest that irregularities in 210-257 km occurred in a region of downward current and the irregularities in 165-178 km and 290-330 km occurred in region of upward current. These observations clearly indicate the existence of a sheared flow of vertical current and hence also a sheared horizontal neutral wind in 165-330 km region.

(H.S.S.Sinha and Shikha Raizada)

Optical Imaging of Plasma Depletions over Kavalur

The optics of the intensified optical imaging system of PRL was modified to improve its angular resolution. The present angular resolution of the system for zenith viewing is 0.6°, 0.3° and 0.07° for fish eye, wide angle and standard lenses, respectively. This system was operated at Kavalur (12° 34' N, 78° 49' E) during March-April, 1998, to study ionospheric plasma depletions. During this campaign, three nightglow lines at 630.0 nm, 777.4 nm and 557.7 nm were used for imaging (**Fig. 5.4**). Extremely sharp depletions were seen, in 630 nm and 777.4 nm lines, in the month of March, 1999. On most of the nights, the depletions started appearing around 2130 LT, became fully developed around 2300 LT, became faint by 0030 LT and finally disappeared by about 0200 LT. The frequency of occurrence of plasma depletions was also very high (58% of the nights) during the month of March. The east-west scale size of these depletions ranged between 170 km and 900 km. The degree of depletion ranged between 3% and 15%. Shallower depletions were observed to have smaller zonal extent. Detailed analysis of images and comparison with other experiments, which were also conducted as a part of I-STEP campaign, is in progress.

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

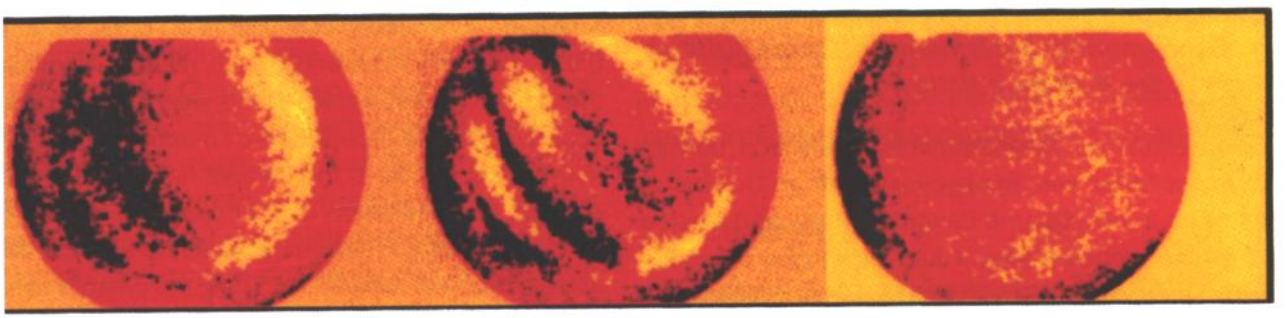

Fig. 5.4 Images of plasma depletions taken in 557.7, 630.0 and 777.4 nm by PRL's Multi-Wavelength All sky Imaging System (MAIS) at Kavalur (12°34'N, 78°49'E).

Further Refinements in the Explanation of Equatorial Temperature and Wind Anomaly (ETWA)

The process of equatorial temperature and wind anomaly (ETWA) is one of the most important aspect which contributes significantly to the thermal balance but is not yet accounted for, by the MSIS model. In order to understand and parameterise the processes involved in the generation of ETWA, a detailed exercise was undertaken using DE-2 satellite data. A plausible explanation of ETWA was offered on the basis of chemical heating due to exothermic reactions and the frictional heating due to the ion-drag effects. However, it was observed that, though, the heating due to the exothermic recombination chemistry has been accounted for at all local times, the ion-drag associated heating was not being explained at times especially during presunset hours. In the course of this study, the above inadequacy was found to be due to the temporal variation in the integrated E-region conductivity and its subsequent loading effect on F-region dynamics over low latitudes during the day. The importance of this process in the overall F-region ion-drag, offered to the neutral wind over the anomaly crests was realised and taken into account by incorporating the temporal variations of integrated E-region conductivities in the existing ion-drag quantification scheme. Ionospheric model IRI90 was made use of along with DE-2 measured thermospheric and ionospheric parameters. Inclusion of this refinement was found to reproduce the ion-drag associated heating realistically at all local times during the day. This is considered as an important step towards formulating realistic models for the low latitude thermosphere (**Fig. 5.5**).

(R. Sridharan and Tarun Kumar Pant)

Short Time Scale Variabilities in 630.0 nm Thermospheric Airglow Intensities over Low Latitude

The dayglow photometer was suitably modified to measure the nightglow intensities also and the instrument was operated in a campaign mode from Waltair (17.7°N, 83.3°E) during March-April 1998. Significant short time scale variabilities are observed on several occasions in both night and dayglow intensities. Discrete fourier transform analysis was performed and the dominant periodicities in the 630.0 nm airglow intensities were found out to be in the range of 30 min to 1.25 hr during both day and night time indicating the passage of gravity waves. Detailed analysis is in progress.

(Alok Taori, D. Chakrabarty, R. Sridharan and R. Narayanan)

Daytime Mesopause Rotational Temperatures from Equatorial Latitude

An experimental campaign was conducted during March-April 1998 from Tirunelveli (8.7°N, 77.8°E) by deploying the multi-wavelength daytime photometer. The rotational temperatures were derived by monitoring two rotational line emissions of the same vibrational band of OH emissions from mesopause region. The temperatures

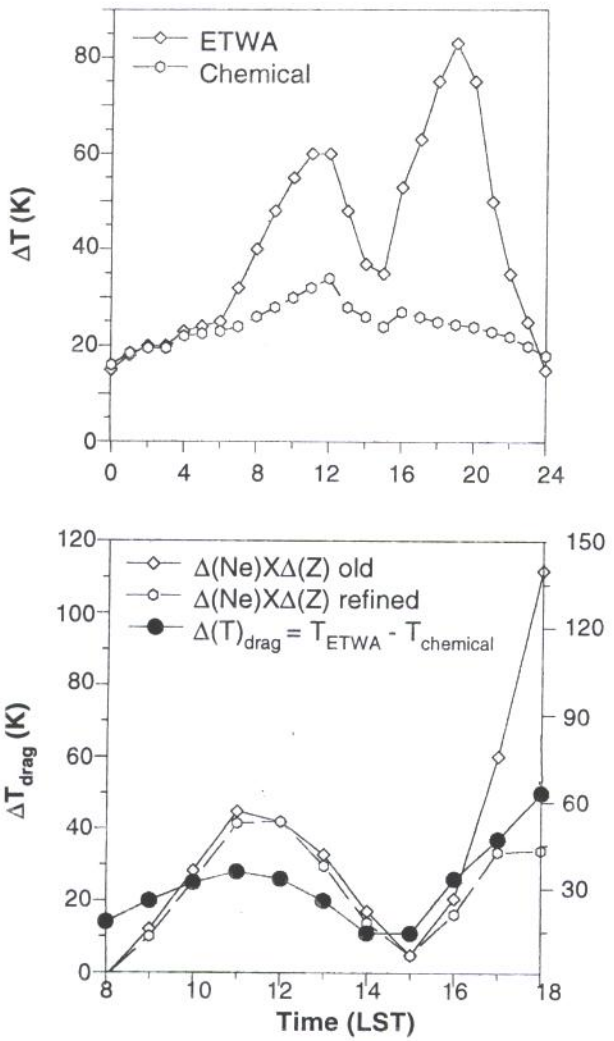

Fig. 5.5 Top : The local time variation of the enhancement in temperature at anomaly crest due to process of ETWA, and the contribution due to exothermic recombination chemistry to above. Bottom : Quantification of ion-drag based on the refined product of changes in electron density and zonal wind.

from the mesopause region exhibit diurnal and day-to-day variabilities. The derived temperatures are significantly different from the MSIS-90 model temperatures and also exhibit oscillatory features.

(Alok Taori and R. Sridharan)

Interaction of Two Long Wavelength Modes in Nonlinear Evolution of Equatorial Spread-F

An investigation is made with two long wavelength modes as initial perturbation in the nonlinear simulation model of ESF to understand a unique observation obtained by Indian MST radar consisting of two plumes with prominent descending structure. This study revealed that the longer wavelength mode developed into bottomside structure, while the second mode developed into multiple plumes. Further, the interaction between the modes has been shown to modify the electric field structures. This interaction is also found to vary considerably depending upon the amplitudes of two long wavelength modes and also the initial phase differences between these modes. By introducing two long wavelength modes as the initial density perturbation with appropriate amplitudes and phase delay, a unique ESF structure similar to the one observed by the Indian MST radar, was reproduced. This work was done in collaboration with Prof. P.B. Rao of NMRF, Tirupati.

(R. Sekar and E.A. Kherani)

Co-ordinated Observations of Equatorial Spread-F Irregularities by VHF and HF Radars

Coordinated observations involving multi-institutions and multi-techniques were conducted as a part of I-STEP campaign during March-April 1998. During this period, simultaneous operation of VHF (53 MHz) and HF (18 MHz) radars, located respectively at Gadanki (13.5°N, 79.2°E, dip. 12.5°N) and Trivandrum (8.5°N, 77.0°E; dip. 0.5°N) was conducted for mapping the structures and dynamics of equatorial spread-F (ESF) irregularities. Simultaneous observations of ESF are available for eight nights. The Doppler spectra observed by both the radars are characterised by simple Gaussian to multi peak complex structures and vary significantly both in height and time. The ESF structures were observed over a height range of 275 - 700 km at Trivandrum and, as expected, at a somewhat lower height range of 225-600 km at Gadanki. It is of interest to note that the maximum mean Doppler velocities observed by HF radar did not exceed 80ms^{-1} while the maximum velocities observed by the VHF radar correspond to 300 ms^{-1} indicating the dispersive nature of ESF irregularities. This work was done in collaboration with a group of scientists from NMRF, Tirupati and SPL, Trivandrum.

(R. Sekar and E.A. Kherani)

Rocket-borne and Radar Studies of Equatorial Electrojet at Different Longitudes

During last 30 years, rocket-borne as well as VHF radar studies have been carried out to investigate the longitudinal features of equatorial electrojet. These locations on three different longitudes are Jicamarca, Peru (12°S, 77°W, dip. lat. 1°S), Alcantra, Brazil (2.3°S, 44°W, dip. lat. 1°S), Thumba, India (8.5°N, 77.5°E, dip. Lat. 0.5°N). Results from all the three locations for noontime conditions were compared for a moderate solar cycle period. Results of electrojet current strength measured by rocketborne magnetometers show that the current density is maximum at 105 km during noon 1100 hrs LT and the density value is 10 Amp/km^2 within an accuracy of 5%. Such features are similar for all the three locations. This altitude coincides with the one where type-I irregularities are observed by radar as well as by rocketborne probes. Type-I irregularities are due to two-stream instability. The two-stream instability is excited when the electron drift velocity exceeds the ion acoustic velocity which is about 350 m/sec at 105 km. Both rocket and radar results show the presence of type-I irregularities at 105 km. These results show that there is no significant longitudinal differences either in intensity or in location of maximum current density of electrojet. Our results show that in electrojet region, polarization electric fields are similar at all the longitudes. Several authors have shown longitudinal difference in electrojet current intensity but our results do not show any such difference.

(S.P. Gupta)

Two-stream Instability during Nighttime over Equator

We have conducted six rocket flights during nighttime from Thumba to measure type-I irregularities, which are due to two-stream instability. We have detected the presence of type-I irregularities on five occasions. On one occasion, we could not see type-I irregularities because that day happened to be magnetically disturbed day. These results show that in night time, eastward electron drift velocity is about 560 m/s. Such drifts are necessary to excite two-stream instability which give rise to type-I instability. Radar measurements over Thumba give a value for drift velocity of about 500 m/s. when type-I irregularities are present. These results show that it is the vertical electric field alone, which drives the electrons in east-west direction. The Cowling conductivity is less in night by a factor of about twenty. This shows that Cowling conductivity is not the sole criterion for two stream instability.

(S.P. Gupta).

Rocket Flight from SHAR to Investigate Equatorial Spread-F

Three rockets were launched from SHAR in 1998 under ISRO-DLR collaborative programme on space research. The rockets were RH-560 Mk-II. Each rocket carried five identical payloads, 1. Resonance cone, 2 Langmuir Probe, 3. Flux gate magnetometer, 4. Impedance probe and 5. Radio Beacon experiment. The objective of the campaign was to investigate the causative mechanism of equatorial spread-F. The rockets were launched when groundbased ionosonde showed the presence of spread-F. Langmuir probe and impedance probe data have been analyzed and large scale irregularities at the base of F region at 250-300 km were seen. These are due to Rayleigh-Taylor instability. Large depletions were seen at the bottom as well as topside of the F-region. Valley in electron density was observed between 150-270 km. These were the first results where measurements were made upto about 425 km height. This work was done in collaboration with Drs.H. Thiemann, A. Piel and C.T. Steigies of Germany.

(S.P. Gupta)

Long Term Changes in Ionosphere

Long term changes in ionosphere as a consequence of the cooling of mesosphere and thermosphere due to the increase in greenhouse gases have been reported recently at high and mid latitudes. Radio sounding data over Ahmedabad for 1955-96 show, after removing the seasonal and solar cycle effects, decreases in the midday and midnight values of f_oF_2, the critical frequency of F_2 layer and h_pF_2, a measure of the peak altitude of F_2 layer. The annual-mean trends indicate decreases of 1.6 MHz and 1.0 MHz in f_oF_2 and 16 km and 10 km in h_pF_2

in four decades for midday and midnight respectively. An increase of 0.3 MHz in four decades is noted in f_0F_1. The published data of f_0F_2 over Kodaikanal, situated near the magnetic equator for the years 1960-95 also show decreases of 0.5 MHz for midday and 0.7 MHz for midnight. The results are consistent with the predictions made by Rishbeth and Roble and with those observed at mid and high latitudes. The radio sounding data therefore contain the signatures of the cooling of upper atmosphere (thermosphere).

(Som Sharma, Bharati Bhatt and H. Chandra)

Leonid Meteor Shower Event

The Leonid meteor shower stream is known to have a strong activity every 33 years. A strong meteor burst had been predicted to occur in 1998 or 1999. Rapid radio soundings were made over Ahmedabad during 16-19 November 1998 to study the ionospheric effects due to the enhanced meteor flux. The ionograms over Ahmedabad show sporadic E layer on 17 November from about 02 hr (LT) to morning hours. The layer was first seen at 130 km and later descended to 100 km. On 18 November, strong sporadic E layer with multiple echoes was seen from midnight onwards. The layer first appeared at 110 km (00 hr) but later descended to 100 km (0230 hr). Upto five multiples were seen between 0230 and 0400 hr. Examination of ionograms of these days over past few years confirm that the sporadic layer was associated with the Leonid shower event.

(Som Sharma and H. Chandra)

Planetary/Cometary Atmospheres

Field Aligned Current and Parallel Electric Field between the Magnetosphere and Ionosphere of Mars

A kinetic model has been developed earlier to study the transportation of ions from Martian ionosphere. This model is extended to estimate the electron current density at different potential differences between the magnetosphere and ionosphere of Mars. For this calculation it is assumed that Mars has a weak dipole magnetosphere whose plasmasheet is connected to the ionosphere along the magnetic field lines. The total electron flux of 5.79×10^8 $cm^{-2}s^{-1}$ is calculated in the Martian magnetosphere corresponding to the downward current density of 1.0×10^{-6} A/m^2 at zero potential difference. The maximum flux of thermal electrons escaping towards the plasmasheet of Mars at zero current density is calculated to be $3.0 \times 10^8 cm^{-2}s^{-1}$. At zero current density the precipitating flux of plasmasheet electron is approximately equal to maximum escape flux of thermal electrons. These results are found to be in reasonable agreement with experimental data obtained from Hyperbolic Retarding Potential Analyzer experiment onboard Phobos 2. This work was done in collaboration with Mr. S.P. Seth of Bhavan's R.A. College of Science, Ahmedabad.

(S.A. Haider)

Dynamics of Martian Ionosphere

Due to very small magnetic field of Mars our knowledge on the magnetosphere – ionosphere coupling processes is almost insignificant as compared to that on Earth. The nightside ionosphere of Mars could be produced either by electron precipitation or plasma transport from dayside to nightside along the terminator. Using the first mechanism, the calculations of ion and electron densities for the dayside and nightside ionosphere of Mars have been reported earlier. In these calculations the continuity equation was solved for chemical equilibrium condition. The horizontal and vertical momentum equations are now included in the continuity equation to understand the dynamics of the ionosphere transporting the plasma from dayside to nightside ionosphere of Mars in the absence of intrinsic magnetic field. A computer programme of complex nature has been developed for this study.

(S.A. Haider)

Cometary Coma

The atomic carbon CI 193.1 nm emission has been observed in the ultraviolet spectra of comae of several comets. The chemistry of this atom has been reported previously using the chemical transport model. Now the intensity of CI 193.1 nm emission is calculated in the inner coma of comet 46P/Wirtanen. The mechanisms that may

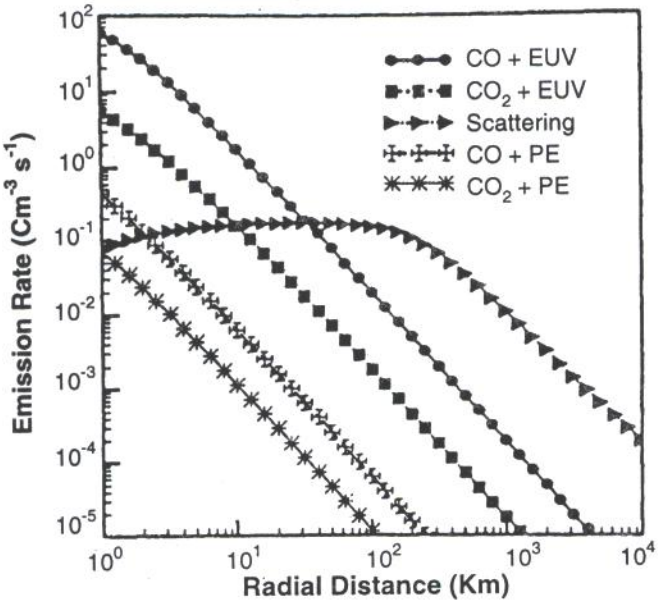

Fig. 5.6 Radial emission rate profiles of CI (193.1 nm) in Cometary Coma.

be important in producing this emission include photodissociative excitation of CO and CO_2, photoelectron impact dissociative excitation of CO and CO_2 and resonant scattering of solar photons. **Fig. 5.6** shows the emission rate profiles of CI 193.1 nm emission produced by these mechanisms. The major source of this emission at distances <40 km is the dissociation of CO. On moving away from the nucleus, the resonant scattering starts picking up and at radial distances greater than 10^2 km this process is predominant. This suggests that beyond few tens of km the emission produced by neutral parent species are proportional to their gas number density indicating that the atmosphere is optically thin to the incoming solar radiation at and beyond these distances.

(S.A. Haider)

Laboratory Astrophysics

Life Time Measurements of NO_2 in the Predissociation Region 399-416 nm

The fluorescence excitation spectra of NO_2 have been studied and life times have been measured in the first predissociation region at the photon excitation wavelengths 399-416 nm at an interval of 0.2 nm and at gas pressures 1, 3, 5, 7, 10 and 15 mTorr using an excimer laser pumped dye laser as the photon source. Three groups of life times have been obtained viz. 35-42, 80-120 and of the order of 0.1 s.

The life time spectra of the static component present in the entire spectral region have been obtained as a function of excitation wavelength at different gas pressures. At a gas pressure of 1 m Torr, the fluorescence decay curves are purely exponential and life times vary from 35 to 42 s. At pressures larger than 5 m Torr, the fluorescence decay is found to be non-exponential at a few incident photon wavelengths with the result that a few more groups of lifetimes are observed. The observed life times are found to increase in value with excitation wavelength upto 405 nm and thereafter, the lifetimes are seen to be more or less constant. Also, the life time values at different wavelengths are found to decrease with in increasing gas pressure. The shorter life times at different gas pressures at the lower wavelength end can be explained in terms of depopulation of the excited state by predissociation and collisions. At low pressures, the predissociation processes are responsible for the decreasing trend of life time values where as at very high pressures, the collisional depopulation is the much dominant mechanism than the predissociation process.

(V. Sivakumaran, K.P. Subramanian, Vijay Kumar and A.P. Gohil)

Self-quenching and Zero-pressure Life Time Studies of NO_2 at 399-490 nm

The self-quenching rate constants and zero-pressure life times for NO_2 have been obtained from the life times measured previously at different gas pressures by the pulse excitation technique in the three spectral regions 465-490 nm, 423-462 nm and 399-416 nm at an interval of 0.2, 0.5 and 0.2 nm respectively. The estimation of zero-pressure life times and self-quenching rate constants have been carried out with an accuracy of ±5% and ±7% respectively for the static component of life time only.

The life times of NO_2 are measured by studying the time decay curves of the fluorescence emission at different excitation photon wavelengths. The fluorescence

from the excited molecules is collisionally quenched by the ground state molecules of the target gas. When the gas pressure in the fluorescence chamber is increased, the fluorescence also increases. After certain critical pressure, the fluorescence signal is found to decrease. At this pressure, the rate of self-quenching overtakes the fluorescence emission rate. It becomes very important to obtain self-quenching rate constants so as to study the effect of collisions on the life time and to obtain life times at zero pressures. Both these physical quantities are obtained from the Stern-Volmer plots drawn between inverse of life time and number density of the target gas.

Self-quenching rate constants in the typical spectral region 423-462 nm only are shown in **Fig. 5.7**. The self-quenching rate constants have been observed to vary from 3.6×10^{-12} to 2.1×10^{-11} cm^3 $molecule^{-1}$ s^{-1} as the excitation wavelength changes from 423 to 462 nm. This clearly indicates that the quenching mechanism is not a single step process and there are pressure-dependent cascade processes involved.

(V. Sivakumaran, K.P. Subramanian, Vijay Kumar and A.P. Gohil)

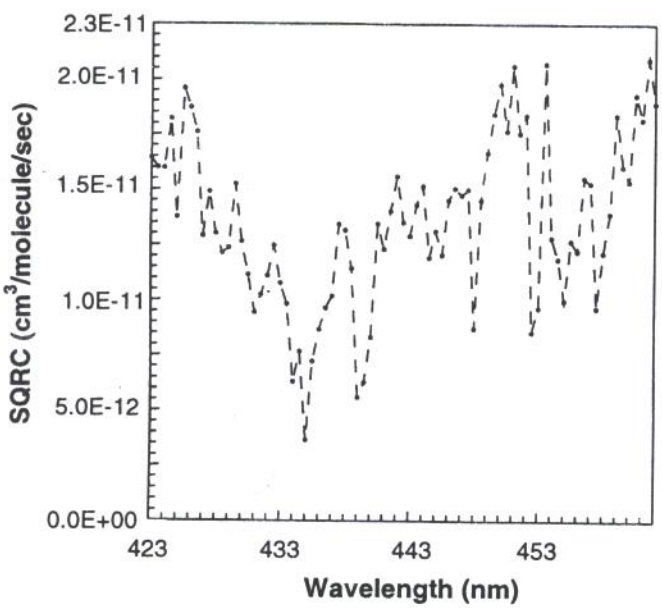

Fig. 5.7 Self-quenching rate constant of NO_2 in the excitation region 423 to 462 nm.

Fluorescence of Sodium Salicylate under Strong Laser Field Conditions

Fluorescence spectrum of sodium salicylate under weak laser field conditions at 308 nm extends from 360 to about 530 nm with a broad maximum near the middle of the spectrum. In case of strong laser fields, there is no shift in the spectrum but a new peak superimposed on the broad maximum is seen in the fluorescence spectrum at 405 nm. This difference in the fluorescence spectrum for a weak and strong field conditions is a significant feature and it can neither be explained by photo-decomposition of sodium salicylate by normal absorption nor by photo-decomposition to higher dissociative states by multi-photon absorption.

The observed fluorescence of sodium salicylate under weak field conditions is due to singlet-singlet transition. The life times have been measured in the present experiment at 405 nm and also at other wavelengths of the fluorescence spectrum. The life time values at all these wavelengths have been found to be of the order of 3.5 ± 0.2 ns. It is suggested that the additional peak observed at 405 nm under strong laser field conditions may be due to triplet-singlet transition which is otherwise forbidden for weak laser fields. The triplet to singlet de-excitation should have larger life time. Work is going on to measure life time at 405 nm under focussed conditions but our endeavour has so far not been rewarded. The fluorescence decay curves for strong laser fields have been found to be complex. Work is continuing in the laboratory in this direction.

(V. Sivakumaran, Prashant Rawat, K.P. Subramanian and Vijay Kumar)

The research programmes of the Earth Sciences and Solar System Division aim to characterise the evolution of the objects in our solar system - Sun, Earth, Moon, Meteorites and the Comets. Signatures of the temporal evolution are present in chemical and isotopic constituents of suitable phases in these objects and their elucidation by sophisticated analytical means constitutes the major activity of this division.

The Division comprises of two areas, (i) Oceanography and Climate Studies and (ii) Solar System and Geochronology. The activities of former group can be broadly classified as (a) Oceanography and Geochemistry and (b) studies of past climate and environment based on continental and marine repositories over various spatial and temporal scales. Similarly the activities of the latter group can be categorised into (a) Elemental and isotopic investigation in meteorites, lunar samples etc. and (b) Geochronology and evolution of continents and oceans. Some of the important results of our investigations are presented below :

Oceanography and Climate Studies

Oceanography

Two cruises were conducted on board FORV Sagar Sampada, one during March 21- April 20, 1998 in the Arabian Sea and the other during January 29 - March 1, 1999 in the Bay of Bengal and the Andaman Sea . In these two cruises, sea water samples were collected for ^{14}C and radium isotope measurements along with standard physical and chemical oceanographic parameters.

The Andaman basin (depth ~ 3200 m) is the deepest part of the Andaman sea which is cut off (at depths below about 1500 m) from the rest of the seas/oceans by the surrounding sills. Several physical and chemical properties measured onboard revealed high level of vertical mixing in the basin. A likely mechanism for the mixing is convection due to the high basal heat flow reported for this region. About twenty water samples have been processed for ^{14}C to estimate the rate of vertical mixing.

Measurements of Ra isotopes in surface water samples from the Bay of Bengal indicate that the eddy diffusivities (using a 2D-diffusion model) are about an order of magnitude higher than those obtained for the Arabian sea (about 10^7 cm^2/sec). This can be reconciled with the fact that the Bay is known to be a seat of cyclones which keep the surface waters turbulent for a large part of the year.

Sediments from the continental margins of the eastern Arabian Sea and the adjacent regions are analysed for major and trace element concentrations, $CaCO_3$, Org. C and for stable isotopes on planktonic foraminiferal species viz. *G. Sacculifer* and *G. Menardii*. One of the gravity cores collected from South-West of Cochin at a water depth of 2700 m was dated by AMS ^{14}C (on planktonic foraminifera) and subjected to measurement of proxies for productivity and near anoxic bottom water conditions (**Fig. 6.1**). Despite the low inorganic productivity (as indicated by Ba/Al and $CaCO_3$ variations) and moderate organic productivity during 9, 19 and 24 kyr BP, the Cr/Al and Mo/Al show high values during the same periods. This suggests a stagnation of the North Atlantic Deep Water (NADW) rather than high productivity in the overlying surface waters of the region.

(R. Agnihotri, R. Bhushan, K. Dutta, S. Krishnaswami, R. Ramesh, R. Rengarajan, M.M. Sarin, A. Sarkar and B.L.K. Somayajulu)

Chemical and Isotopic Studies of the Headwaters of the Yamuna

Yamuna is one of the large rivers draining the Himalaya. We have initiated a major project to study the chemical and isotopic composition of (i) the Yamuna and its tributaries in the Lesser and Higher Himalaya, and (ii) the river bed sediments and selected bed rocks of the drainage basin. The parameters being measured are the major ions, Ca, Mg, Na, K, HCO_3, SO_4, Cl, F and NO_3, and minor and trace elements, Sr, Ba, Re; and isotopes, $\delta^{18}O$, δD and $^{87}Sr/^{86}Sr$. These results will be used to assess the carbonate and silicate weathering rates in the area, and the sources of Sr isotopes to the rivers. The first field campaign was carried out in October, 1998 and a total of 34 river water and 25 river bed sediment samples have been collected. The analyses of major ions and stable isotopes have been completed. The major cation abun-

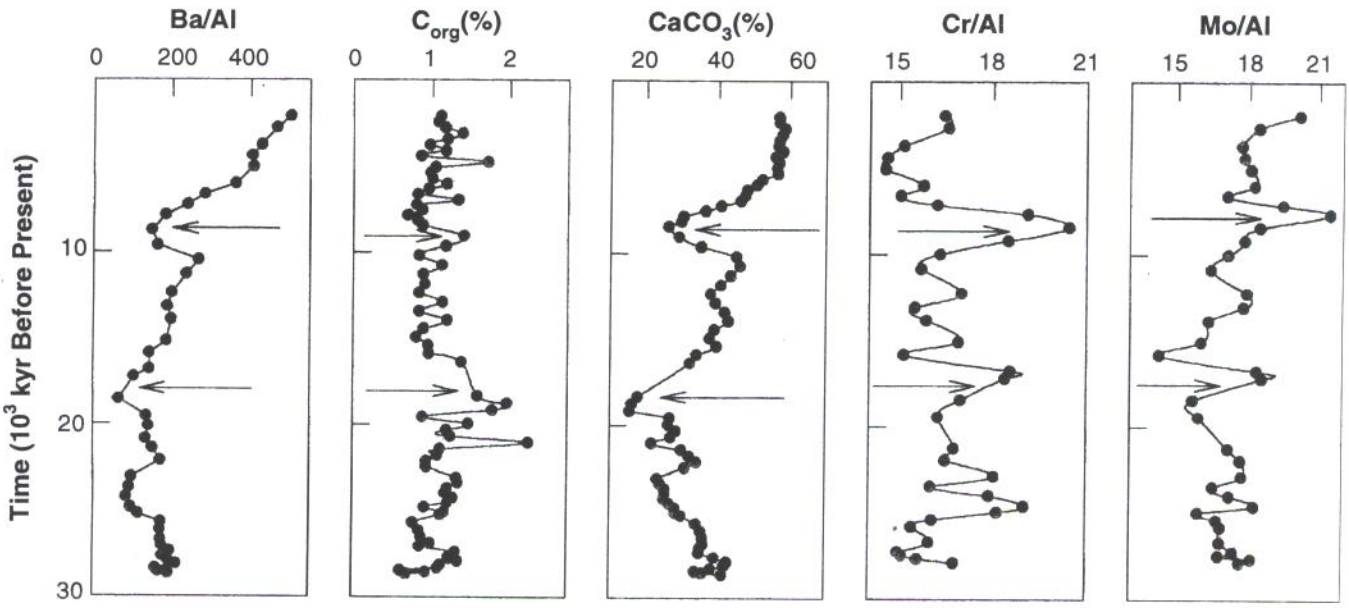

Fig.6.1 Variation of Ba/Al, C_{org}, $CaCO_3$, Cr/Al, and Mo/Al in a sediment core from South-Eastern Arabian Sea. The depth in sediment core has been converted to time based on ^{14}C age in foraminifera. Parameters Ba/Al and $CaCO_3$ indicate productivity, C_{org} indicate preservation, and Cr/Al, Mo/Al indicate anoxicity.

dances range between 180 to 3350 μM, the highest concentrations are observed in the Asan and the Giri rivers flowing around Dehradun, which have high concentrations of SO_4. For comparison, headwaters of the Ganga have a range of 250 to 1585 μM for the major cations. The interrelation between $\delta^{18}O$ and δD in these waters has a slope of 6.2, lower than that of the Ganga head waters which have a value of 7.5, indicating that these waters have undergone evaporative loss.

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

River Transport of Carbon to Oceans

Rivers are the chief carrier of water, salt, organic matter and mineral particles from land to oceans; and support extensive flora and fauna on their flood plains and in water. Under the national LOICZ (Land Ocean Interaction in the Coastal Zone) programme, we have initiated a detailed geochemical study of the Godavari river and its major tributaries originating in the different geographic zones of the basin. Our study aims to provide answers to (i) How much carbon of terrestrial origin is transported and processed by rivers ? and (ii) What is the role of rivers in the global carbon cycle ? An extensive sampling of the river waters has been carried out during November, 1998 and March 1999, representing the medium and lean flow conditions in the river basin. The samples have been analyzed for major ions (Na, K, Mg, Ca, HCO_3, Cl, NO_3, SO_4) together with dissolved inorganic carbon (DIC), particulate nitrogen and carbon contents. The results obtained so far suggest that the transport of DIC through the Godavari river is $3.0 \times 10^{12} gCyr^{-1}$, about half of which is contributed from the tributaries. Further studies on the transport of particulate and dissolved organic carbon are in progress.

(K. Balakrishna and M.M. Sarin)

Evidence of a Strong Monsoon Intensity at 4Ma from Isotopic Studies of Siwalik Sediments

Siwalik hills in northern India are made up of materials resulting from denudation of slopes of the Himalayan Mountains and their deposition on the flood plains of the foreland basin. These are now exposed at several places along the northern boundary of the Indian sub-continent and offer a promising repository to study the variations in

monsoonal intensity. A characteristic feature of the Siwalik sediments is the presence of palaeosols which developed during brief successive pauses in sedimentation. The palaeosols contain pedogenic carbonate, clay minerals, organic matter etc. which are sensitive proxy recorders of climatic variations.

Soil samples were collected from Haripur-Kolar section of the Indian Siwalik in Himachal Pradesh. The area is situated at the sensitive fringe of monsoonal storm tracks and has significantly more rainfall compared to the Potwar Siwalik studied earlier. Sampling was done from Pinjor formation of upper Siwalik corresponding to the age range of 5.2 to 1.6 Ma. The palaeomagnetic work carried out in the same section (2375 m in thickness) at Wadia Institute of Himalayan Geology allowed us to assign ages to individual palaeosol horizons.

The stable isotopic compositions of organic matter, carbonate and clays in palaeosols have been analysed to reconstruct the nature of past vegetation associated with soil formation (**Fig. 6.2**). This shows an episode of negative excursion in the carbon isotope value of the carbonates and in associated organic material at 4 Ma. We interpret this excursion as caused by intensified monsoonal activity. This inference is in concordance with the observation of prolific growth of upwelling prone planktonic foraminifera in the south western Arabian Sea at 4Ma based on DSDP cores. To strengthen our conclusion we have sampled another Siwalik section in Jammu previously analyzed for palaeomagnetic dating. Isotopic analyses on this new set of samples are in progress. A crucial point in the interpretation of data is the age assignment and the earlier work is held to be unsatisfactory by many workers. Therefore, we have also undertaken age determination of the Jammu Section samples by fission track and Ar-Ar methods. This work is being done in collaboration with R. Mohindra and J. Thomas of Wadia Institute of Himalayan Geology, Dehra Dun.

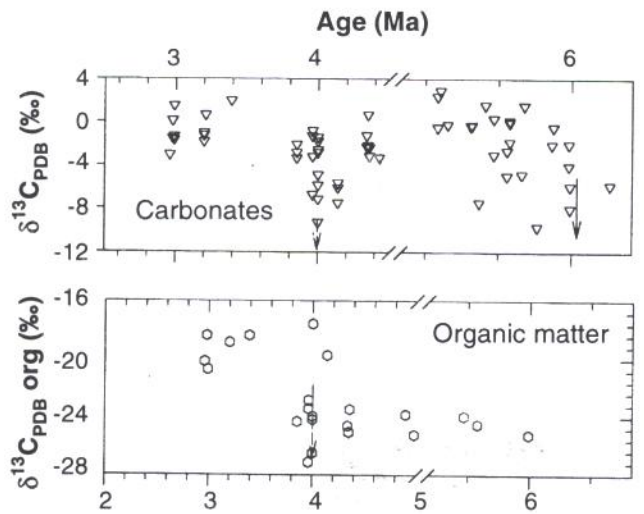

Fig. 6.2 Stable carbon isotopic composition of soil carbonate and soil organic matter from Siwalik sediments in Himachal Pradesh plotted against the age of the samples. The sharp decrease in ^{13}C / ^{12}C ratio at 4 Ma indicates an episode of intensification of Asian Monsoon.

(S.K. Bhattacharya, P. Ghosh, R.A. Jani, J. T. Padia and K. Pande)

Radiocarbon Dating Laboratory

A vacuum graphitization system developed for preparation of targets for Accelerator Mass Spectrometry (AMS) was used to measure ^{14}C in a set of control samples (standards, background and a few known-age materials) at the AMS facility at the University of Arizona. Good agreement between the measured and expected activity shows that the new system is fully operational.

Lacustrine sediments in Lamayuru basin have been dated to ascertain their antiquity and the palaeoseismic events. The chronology shows that the lake formation took place at around 40 ka. A seismic event was also recorded after 23 ka.

Dating of organic carbon from Kaveri River flood plains shows high sedimentation rate around ~ 1300 years B.P. near Dalavyapalayam, probably due to a flooding event caused by stronger monsoon.

Raja Nal Ki Tilla (Uttar Pradesh) has been dated to c. 1030 to 1420 BC which helps fixing the date of pre-iron settlement in Northern Vindhyas.

The ^{14}C activity of a 30 metre lacustrine varve sequence at Garbiyang in central Himalaya shows that the sequence commenced around 24 kyr BP and terminated around 17 kyr BP i.e. during the last glacial maxi-

mum. Sedimentological analysis of these deposits also suggests that fine silty clay which is a major part of these varves should have been deposited during the glacial maximum. This work is in continuation of Goting varve sequence which has been dated earlier indicating regionally extensive varve sedimentation in the higher Central Himalaya during the glacial period (collaborative work with Wadia Institute of Himalayan Geology, Dehra Dun and Jawaharlal Nehru University, New Delhi).

(Sheela Kusumgar and M.G. Yadava)

Dryland Fluvial Record

Dryland fluvial systems have shown potential for reconstructing the past climates. Careful field investigation of fluvial sediments in Thar Desert and its margins indicated that these can provide a record of the changes in the monsoon precipitation. Our studies in the Mahi basin in the transitional zone of humid south and semi-arid north indicated that the river has preserved records of the past 130 kyrs and that it responded to changes in the global climate. For the present study a 35 m thick section at Rayaka (near Baroda) was analysed with luminescence techniques. Important result from this study are : (i) the basal marine fauna rich clay, placed by several groups at 240 ka in fact may reflect a deposition at 130 ka sea level high (Oxygen Isotopic Stage 5); (ii) the river had a major aggradational phase during 50-30 kyrs horizon and (iii) the upper red soil marker horizon correspond an age of 40 to > 25 ka at variance with the earlier suggestion of it being of last interglacial age 130 ka. A regional synthesis of the fluvial records is in progress especially as the work on the Luni and Sabarmati basins has been completed. This was done in collaboration with the M.S. University, Baroda.

(N. Juyal and A. K. Singhvi)

Palaeoflood Records

Fine sand, silt and clay dominated Slack Water Deposits (SWD's) are formed during the flood events in the tributary valleys. These deposits are used to ascertain the timing and magnitude of past flood events beyond the historical record. Three SWD have been investigated at Sindri-Bhuka section in Central Luni basin. Luminescence dating of these deposits indicated that (i) River Luni experienced 17 major floods during the past 800 years and during the past 200 years three major floods occurred (ii) A clustering of floods between the period 1000 years and 500 years is seen with reduced floods during the period 500-200 years (iii) These observations are in close conformity with the Global climatic change (i.e. the medieval warming and the little ice age). Similar clustering of large floods are also seen in the R. Narmada reflecting a regional record of wetter conditions. This work was done in collaboration with Pune University.

(Navin Juyal, Praveen Mishra and A.K. Singhvi)

Hydrology Studies

A field survey of groundwater and soil-air was undertaken in parts of Cambay basin. Of the twelve soil-air samples analysed, only one sample ~ 100 m away from the thermal springs of Tuwa, showed helium concentration (7.0 ppm) higher than the atmospheric background (5.3 ppm). All other soil air samples were near the atmospheric value. However, groundwater samples showed dissolved helium concentration significantly higher (up to > 200 times) than the atmospheric equilibration concentration (0.056 ppm).

In **Fig.6.3** contours of the logarithm of helium anomaly (i.e. Log_{10} (measured Helium - 0.056)) in groundwater samples from the study area are shown. Superposed on this are the traces of major basement faults in the region. It is seen that areas with high anomalous helium concentration overlie some of the major basement faults, particularly on the western flank of Cambay Graben and on the Eastern Cambay Basin Bounding Fault (ECBBF). On the eastern flank, the highest helium anomalies are associated with the thermal springs of Lasundra and Tuwa.

Analogous to helium, enhanced groundwater temperatures are seen to overlie the basement faults on the western flank of the Cambay Graben and around the thermal springs of Lasundra and Tuwa on the eastern flank. It is seen that groundwater temperature and helium are generally associated. This association is indicative of active hydrothermal circulation involving sedimentary deposits and underlying basaltic basement in the study area. It also suggests that the hydrothermal activity is facilitated

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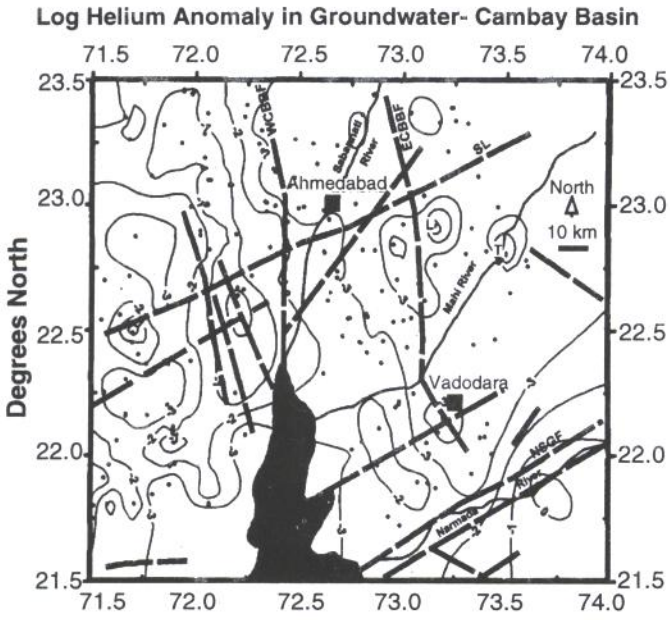

Fig.6.3 Contours of the logarithm of Helium anomaly in ground water. Superposed on these are the traces of major basement faults in the region. The sample locations are marked by dots. The helium concentration between successive contours changes by a factor of 10.

by the presence of basement faults.

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

Evidence for Crustal Carbon in the Mantle Source Region for Carbonatites.

Carbonatites form from deep mantle melts that are believed to incorporate recycled crustal carbon. Evidences in favour of this hypothesis are circumstantial and come from the study of radiogenic (Nd-Sr-Pb) isotopes showing mantle signatures. We have now found direct evidence for this through a study of stable isotope systematics in the carbonatites of eastern India. The carbon isotopic composition of three of these complexes (viz. Sung Valley, Swangkre and Samchampi) are homogeneous, unlike most of the carbonatites world-wide , suggesting batch crystallization of these rocks under plutonic conditions. The oxygen isotopic compositions of all the three complexes are consistent with their derivation in equilibrium with mantle silicates, whereas the carbon isotopic rates are higher than that of normal mantle (-5 to -8 per mil). The homogeneity of the isotopic compositions, absence of ^{18}O enrichments, co-precipitation of calcite and dolomite in isotopic equilibrium and the absence of any crustal contamination effects, preclude the possibility of any change in the carbon isotopic composition of the carbonatite rocks/magmas by magmatic or secondary fractionation processes. Therefore the carbon isotopic composition of these carbonatites directly reflect their source regions. All the three complexes probably belonged to a single magmatic episode, the higher carbon isotope ratio (- 3.2 per mil) being a clear evidence for the incorporation of recycled crustal inorganic carbon in mantle melts.

(R. Ramesh and J.S. Ray)

Re-Os Studies in Black Shales from the Lesser Himalaya

Studies of Re-Os abundances and $^{187}Os/^{188}Os$ in black shales from the Lesser Himalaya have been carried out with two broad goals (a) to obtain spatial distribution of Re-Os concentrations and $^{187}Os/^{188}Os$ in black shales from the region and (b) to use ^{187}Re - ^{187}Os pair as a chronometer. These studies provide better constraints on (i) the chronological and stratigraphic correlation between the various black shale deposits of the region and (ii) the potential of these black shales in contributing to the present day Os isotope systematics of rivers draining the Himalaya and hence to the Os isotope evolution of the ocean. The important findings are :

i. the Re-Os isochron ages of black shales from the Maldeota and Durmala underground mines of the outer belt of the Lesser Himalaya are 554 ± 16 Ma and 552 ± 33Ma, indistinguishable from each other within experimental uncertainties. the ages of these samples, occurring ~ 15 m above the Krol-Tal (Pc-C) boundary, are consistent with biostratigraphy and those reported for Pc-C boundaries, from other locations in the world. The consistency in ages indicates that in these mine samples the Re-Os system has remained closed since (or soon after) the sediment deposition.

ii. Preliminary data on the inner belt samples yield an isochron age of 839 ± 138, higher than that obtained

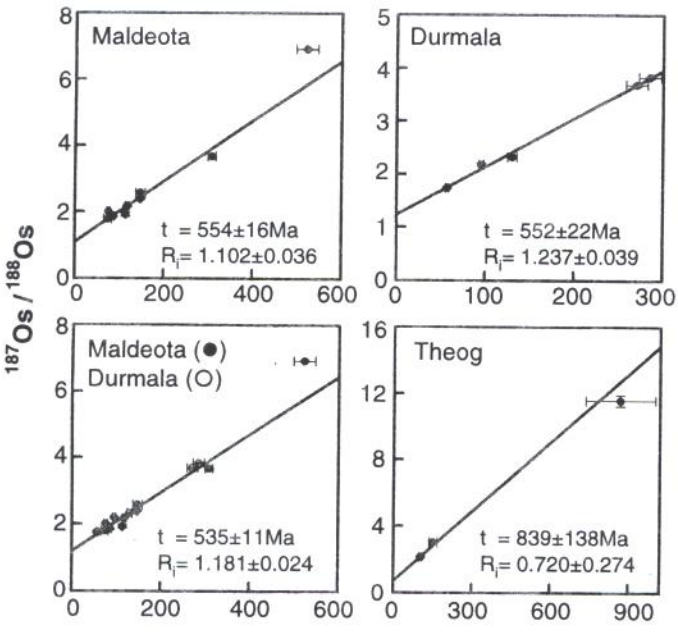

Fig.6.4 Isochron diagrams for the Maldeota, Durmala and Theog black shales. The ages(t) and the initial $^{186}Os/^{186}Os(R_i)$ are given.

for the outer belt black shales. This, if verified by more measurements, would suggest that the inner belt sediments are older than those from the outer belt by a few hundred million years.(**Fig.6.4**)

iii. Based on a simple budget model, the temporal changes in either the Os flux from the HTP rivers or their $^{187}Os/^{188}Os$ to produce the observed variations in sea water $^{187}Os/^{188}Os$ over the past ~ 25 Ma was calculated. The results show that it is difficult to account for these changes via weathering of black shales based on constant flux or constant $^{187}Os/^{188}Os$ ratio models, however, if both the Os flux and $^{187}Os/^{188}Os$ varied with time the increase in oceanic $^{187}Os/^{188}Os$ can be accounted for more easily. The model predictions need to be tested through direct measurements of Os isotope systematics in HTP rivers.

(S. Krishnaswami, Sunil K Singh and J. R. Trivedi)

Effect of Horizontal Resolution on the Sensitivity of a Climate Model

We have examined whether the similarity of continental scale climatology of present day northern summer monsoon at two different horizontal resolutions of an atmospheric general circulation model persists when summer insolation changes from present day values. We find that there are considerable differences in the sensitivity of the monsoon strength between the two resolutions. At higher (lower) horizontal resolution, the monsoon seems to be more sensitive to decrease (increase) in insolation. We have shown that these differences in sensitivity are mainly a result of land surface energy budgets, (especially latent heat flux and net downward solar radiation reaching the surface) between the two resolutions in the present day monsoon simulations. Thus, similar large scale features of the present day monsoon at different horizontal resolutions do not guarantee similar sensitivities to past changes in insolation. This work was done in collaboration with scientists at IISc, Bangalore.

(D. Jagadheesha and R. Ramesh)

The Half-life of the ^{32}Si : A New Estimate Based on Varved Lake Sediments

The half-life of ^{32}Si is still not accurately quantified as the reported ages vary from 101 to 330 years. We attempted to determine the half-life based on decay of cosmic ray produced ^{32}Si in a varved sediment core. In this study, five sediment cores (1m long) were collected from a varved lake in Kassjon, North Sweden and sample taken from various depths. These samples are precisely dated by annual varve counting technique for the past 1000 years. The biogenic silica from these sediments at different depth intervals was extracted at University of Liverpool and brought to PRL for radio chemical separation, purification and assay of ^{32}Si using standard procedures. Assuming that the specific activity of ^{32}Si deposited on the sediment surface has remained constant over a few centuries the decrease of ^{32}Si activity with depth yields 178 ± 10 years as the half life (**Fig.6.5**). This result reinforces the use of ^{32}Si as a geochronometer to study earth surface processes that have occurred during the last millennium.

(V. N. Nijampurkar and D. K. Rao)

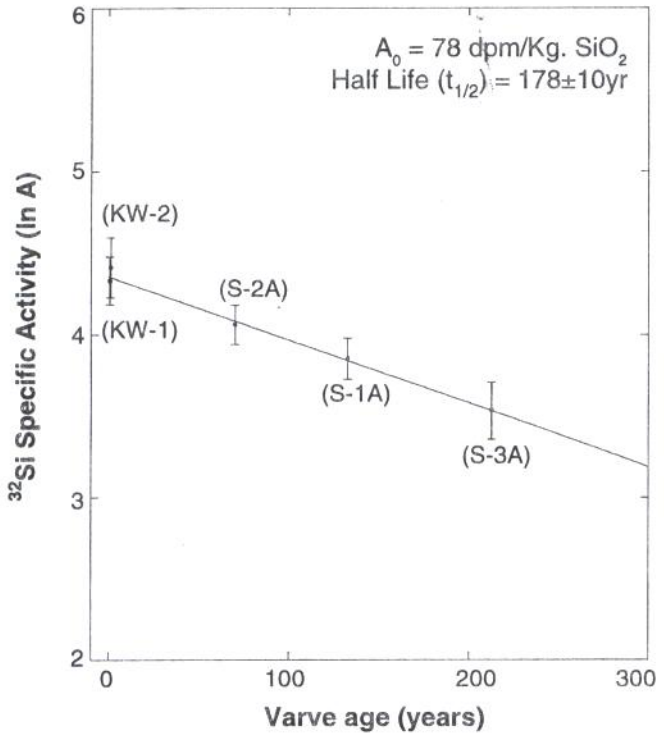

Fig.6.5 Specific activity of ^{32}Si (dpm/kg SiO_2) of three sediment samples S-1A, S-2A and S-3A plotted against their age. Using specific activity of two water samples KW-1 and KW-2 to represent the modern value the slope of the best fit line yields a half-life value of 178 ⑥ 10 years.

Accumulation of Ice at Dakshin Gangotri, Antarctica

A 60 m long ice core was raised near the Indian station, Dakshin Gangotri from East Antarctica (70° S, 12°E) in 1992. The electrical conductivity was measured to monitor the acidity of the core with resolution of 20cm. The analysis of ^{18}O has been done at intermittent depth intervals. This analysis provides information on annual accumulation of ice and past climatic conditions. The results indicate that the annual deposition of ice is ~ 20 cm at this location. For ^{210}Pb analysis, samples of 120-200 cms depth range are combined upto a depth of 20 m of the ice core and ^{210}Pb activity is measured via it's daughter isotope ^{210}Po. The accumulation rate of ice is estimated to be ~ 19 cm/yr based on the decay of ^{210}Pb activity from the surface to the bottom in the ice core.

(V.N. Nijampurkar and D.K. Rao)

Solar System and Geochronology

Early Evolution of the Solar System

Heat Source for Melting of Planetesimals in Early Solar System

Formation ages of differentiated meteorites inferred from studies of extinct nuclides (^{53}Mn, ^{107}Pd, ^{182}Hf) and long-lived nuclides (e.g. ^{147}Sm, ^{87}Rb) suggest that they evolved as a consequence of melting and differentiation of their parent bodies within the first twenty million years of the formation of the solar system. Decay of the short-lived nuclide ^{26}Al to ^{26}Mg with a half-life of 0.7 million years was postulated to provide the heat required for early melting of planetesimals representing the parent bodies of these meteorites. Last year, we reported preliminary results obtained from studies of Al - Mg isotopic systematics in plagioclase grains from the differentiated meteorite Piplia-Kalan, belonging to the eucrite group, that provided a strong hint that ^{26}Al could indeed be the heat source for early melting of planetesimals. A detailed ion microprobe study of Al - Mg composition was carried out in two lithologies from one section (PK-97-1) of this meteorite. The results show that plagioclase with ^{27}Al/^{24}Mg values ranging from 3000 to 7000 have ^{26}Mg excesses of ~ 15 to 30‰ while the pyroxene grains with low Al / Mg ratios have normal Mg isotopic composition. Our data show that ^{26}Al was present at the time of formation of the eucrite Piplia Kalan and yield an initial ^{26}Al / ^{27}Al = (7.5 ± 0.9) × 10^{-7} ($2\sigma_m$). The isotopic data also suggest low temperature metamorphism on the parent body of Piplia Kalan that affected the plagioclase, but not the pyroxenes. This is the first unambiguous evidence for the presence of ^{26}Al in a differentiated meteorite and supports the suggestion that ^{26}Al was the heat source for melting of planetesimals early in the history of the solar system. The inferred initial abundance of ^{26}Al/^{27}Al indicates that melting, differentiation and crust formation in the parent body of Piplia Kalan was complete within five million years of the formation of the solar system.

(G. Srinivasan, J. N. Goswami and N. Bhandari)

Isotopic Constraints on the Formation of the Parent Body of Piplia Kalan Eucrite

A correlated study of extinct radionuclides and long-lived nuclides in eucrites can provide time constraints on the formation and evolution of basaltic crust on their parent body. Following our discovery of ^{26}Al in the Piplia Kalan eucrite, further studies have been initiated using thermal ionization mass spectrometry (TIMS) technique to: (i) confirm the presence of ^{26}Al; (ii) determine the absolute age of Piplia Kalan using long-lived radionuclides (^{147}Sm-^{143}Nd, ^{87}Rb-^{87}Sr) and (iii) determine the abundances of short-lived radionuclides ^{146}Sm, ^{53}Mn and ^{60}Fe to further constrain its origin. The perliminary results from TIMS studies confirm the presence of ^{26}Al inferred from ion microprobe data. The initial $^{26}Al/^{27}Al$ ratio obtained from TIMS data is higher by a factor of about three than that inferred from ion microprobe data; further work is planned to address this issue. The absolute age of this meteorite using the ^{147}Sm chronometer is (4.574±0.100) billion years and the initial $^{146}Sm/^{144}Sm = (6.7\pm1.5)\times10^{-3}$. In plagioclase the measured $^{87}Sr/^{86}Sr = 0.69923 \pm 0.00004$, and we calculate an initial $(^{87}Sr/^{86}Sr) = 0.69900 \pm 0.00004$, which is indistinguishable from the lowest initial inferred for the differentiated basaltic achondrites. Further studies are in progress to obtain a self-consistent scenario for the evolution of this meteorite that can accommodate all the isotopic data. This work was carried out in collaboration with Prof. G.J. Wasserburg at California Institute of Technology and Dr. D. Papanastassiou at Jet Propulsion Lab at Pasadena, California.

(G. Srinivasan)

Absence of Short-lived Nuclides in Earliest Solar System Solids: A New Model

A large number of Ca-Al-rich refractory inclusions in primitive meteorites incorporated the short-lived nuclide ^{26}Al at the time of their formation with an initial $^{26}Al/^{27}Al$ ratio of 5×10^{-5}. However, there exist inclusions and refractory phases that are devoid of ^{26}Al. Our studies have shown that objects free of ^{26}Al are also devoid of the short-lived nuclide ^{41}Ca. Interestingly, results obtained elsewhere and by us indicate that these objects often show enrichment in the neutron-rich stable isotopes, ^{48}Ca and ^{50}Ti, and are also characterized by high abundance of refractory trace elements compared to average solar system value. Both these features in fact suggest their formation very early in the history of the solar system. Thus, the absence of the short-lived nuclides, ^{26}Al and ^{41}Ca, in these early solar system solids is intriguing. Several suggestions like heterogeneity in the distribution of these nuclides and formation of these objects from large clumps of interstellar matter devoid of ^{26}Al has been proposed. However, none of them appear to be satisfactory. We now suggest that the absence of the short-lived nuclides in them can be explained if we assume a stellar source for these nuclides. Numerical simulation studies of impact of stellar wind (shock wave) with the protosolar cloud suggest that the injection of shock wave material containing the radoactivities into the collapsing cloud is not instantaneous and takes place a few 10^5 years after the impact. We propose that the refractory objects devoid of the short-lived nuclides were indeed some of the first solar system solids that formed near the central zone of the collapsing protosolar cloud prior to the arrival of the short-lived nuclide injected from a stellar source (**Fig.6.6**). Our proposal can also explain the stable isotopic anomalies and trace element abundance patterns in these objects.

(S. Sahijpal, K. K. Marhas and J. N. Goswami)

Genetic Relationship between Calcium-Aluminium Inclusions and Chondrules

Calcium-aluminium-rich inclusions (CAIs) and chondrules are important constituents of primitive meteorites, however, the relationships between these objects are still unclear. Many authors have suggested that CAIs, Al-rich chondrules, and normal ferromagnesian chondrules may represent a continuum of compositions and, thus, could be genetically related. Chemical mixing calculations suggest that CAI fragments mixed with normal ferromagnesian chondrules reproduce the bulk composition of Al-rich chondrules. Further, Al-rich objects have lower $^{26}Al/^{27}Al$ (1×10^{-5}) compared to CAIs (5×10^{-5}). If the distribution of ^{26}Al in the solar nebula was homogeneous, this difference would imply formation of the Al-rich objects about two million years after the CAIs.

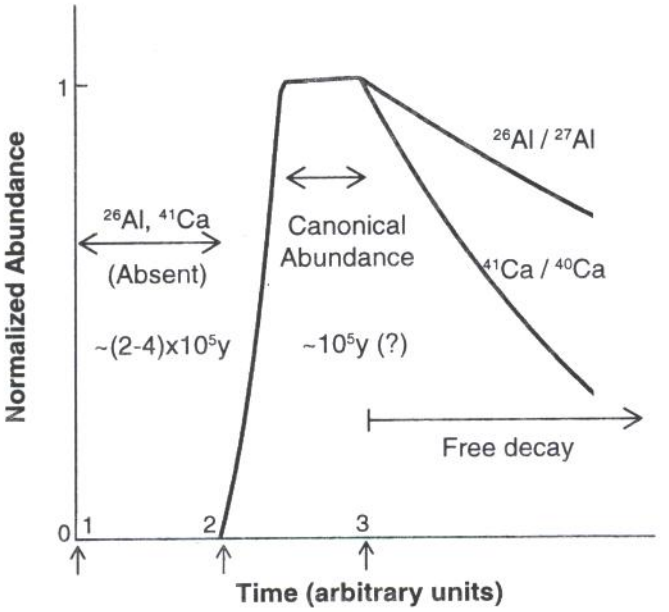

Fig.6.6 Schematic representation of the expected abundances of ^{26}Al and ^{41}Ca relative to their stable counterparts (^{27}Al, ^{40}Ca) in the solar nebula as a function of time. The arrows mark (1) the time of impact of the stellar outflow (shock front) containing freshly synthesised material on the proto solar cloud, (2) onset of injection of radionuclides and (3) the end of injection respectively.

A chondrule-like object in the Sharps meteorite containing an irregularly-shaped hibonite-spinel-rich inclusion (similar to CAI), embedded in a nepheline-like mesostasis of the host object, was identified. The presence of relict CAI in a chondrule suggests that CAI forming process preceded the formation of chondrules and Al-rich chondrules may have originated by mixing CAIs and normal chondrules. Mg-Al isotope studies of the hibonite grains did not reveal resolvable ^{26}Mg excess. The low value for initial ^{26}Al/^{27}Al in this object (< 5×10^{-6}) suggest formation of this hibonite several million years after the CAIs. Alternatively, the hibonite could have formed early and the Mg isotopic systematics in it was reset by a late stage secondary event several million years after its formation; this event may have also led to the formation of this chondrule like object. This work was carried in collaboration with A. Bischoff at Institut für Planetologie, Münster, Germany.

(G. Srinivasan)

Cosmogenic Records and Noble Gases in Meteorites

Carrier of Noble Gases in Diamond Free Ureilite ALH 78019

Ureilites are the only achondrites that contain microns sized diamonds. It has been shown that these diamonds are the principal carriers of the large amounts of noble gases present in ureilites. The only ureilite that has been shown to be free of diamonds but has high amounts of noble gases, is ALH78019. Amorphous carbon is suggested to be the carrier of noble gases in this meteorite. Diamonds in ureilites also carry very light nitrogen ($\delta^{15}N \leq -110‰$). We investigated N and noble gases in ALH78019, to ascertain the carrier of noble gas and N as well as to understand the N isotopic composition of the ureilite. We have separated acid resistant (HF/HCl) carbonaceous phase from this meteorite and further treated it with oxidizing acids to remove the amorphous carbon and analyzed N and noble gases in these separates by combustion. While amorphous C combusts at < 500°C, diamond and graphite combust at much higher temperatures. As shown in **Fig.6.7**, in the HF/HCl residue, most of N and Ar are released by 400°C, while most of the C is combusted at 800-1000°C. This clearly shows that amorphous C is the carrier of gases in ALH78019. The C combustion profile also suggests that most of the C in ALH78019 is graphite and is gas free. This is further confirmed by the fact that the low temperature peak of gases is totally absent in the oxidized residue, which is free of amorphous carbon. Also the lowest measured $\delta^{15}N$ = - 21‰, in the HF/HCl residue is much different from the value of - 110‰, for the ureilite diamond, further confirming the absence of diamonds in ALH78019. This work was carried out in collaboration with Prof. U. Ott of Max Planck Institute fur Chemie, Mainz, Germany.

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

Cosmogenic Records in Recently Fallen Meteorites

Meteorites can be used to monitor cosmic ray flux in the interplanetary space. Several meteorites belonging to different classes e.g. Piplia Kalan (eucrite), Lohawat (howardite), Didwana (chondrite), Mbale (L5 chondrite)

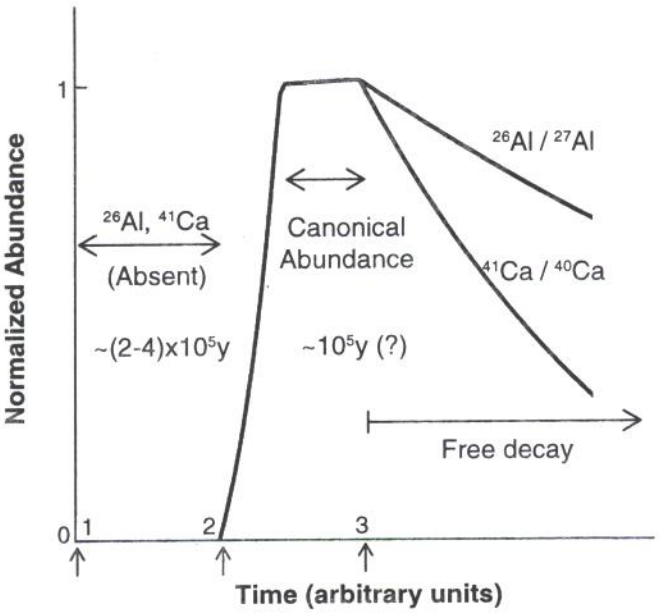

Fig.6.6 Schematic representation of the expected abundances of ^{26}Al and ^{41}Ca relative to their stable counterparts (^{27}Al, ^{40}Ca) in the solar nebula as a function of time. The arrows mark (1) the time of impact of the stellar outflow (shock front) containing freshly synthesised material on the proto solar cloud, (2) onset of injection of radionuclides and (3) the end of injection respectively.

A chondrule-like object in the Sharps meteorite containing an irregularly-shaped hibonite-spinel-rich inclusion (similar to CAI), embedded in a nepheline-like mesostasis of the host object, was identified. The presence of relict CAI in a chondrule suggests that CAI forming process preceded the formation of chondrules and Al-rich chondrules may have originated by mixing CAIs and normal chondrules. Mg-Al isotope studies of the hibonite grains did not reveal resolvable ^{26}Mg excess. The low value for initial ^{26}Al/^{27}Al in this object (< 5×10^{-6}) suggest formation of this hibonite several million years after the CAIs. Alternatively, the hibonite could have formed early and the Mg isotopic systematics in it was reset by a late stage secondary event several million years after its formation; this event may have also led to the formation of this chondrule like object. This work was carried in collaboration with A. Bischoff at Institut für Planetologie, Münster, Germany.

(G. Srinivasan)

Cosmogenic Records and Noble Gases in Meteorites

Carrier of Noble Gases in Diamond Free Ureilite ALH 78019

Ureilites are the only achondrites that contain microns sized diamonds. It has been shown that these diamonds are the principal carriers of the large amounts of noble gases present in ureilites. The only ureilite that has been shown to be free of diamonds but has high amounts of noble gases, is ALH78019. Amorphous carbon is suggested to be the carrier of noble gases in this meteorite. Diamonds in ureilites also carry very light nitrogen ($\delta^{15}N \leq -110‰$). We investigated N and noble gases in ALH78019, to ascertain the carrier of noble gas and N as well as to understand the N isotopic composition of the ureilite. We have separated acid resistant (HF/HCl) carbonaceous phase from this meteorite and further treated it with oxidizing acids to remove the amorphous carbon and analyzed N and noble gases in these separates by combustion. While amorphous C combusts at < 500°C, diamond and graphite combust at much higher temperatures. As shown in **Fig.6.7**, in the HF/HCl residue, most of N and Ar are released by 400°C, while most of the C is combusted at 800-1000°C. This clearly shows that amorphous C is the carrier of gases in ALH78019. The C combustion profile also suggests that most of the C in ALH78019 is graphite and is gas free. This is further confirmed by the fact that the low temperature peak of gases is totally absent in the oxidized residue, which is free of amorphous carbon. Also the lowest measured $\delta^{15}N$ = - 21‰, in the HF/HCl residue is much different from the value of - 110‰, for the ureilite diamond, further confirming the absence of diamonds in ALH78019. This work was carried out in collaboration with Prof. U. Ott of Max Planck Institute fur Chemie, Mainz, Germany.

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

Cosmogenic Records in Recently Fallen Meteorites

Meteorites can be used to monitor cosmic ray flux in the interplanetary space. Several meteorites belonging to different classes e.g. Piplia Kalan (eucrite), Lohawat (howardite), Didwana (chondrite), Mbale (L5 chondrite)

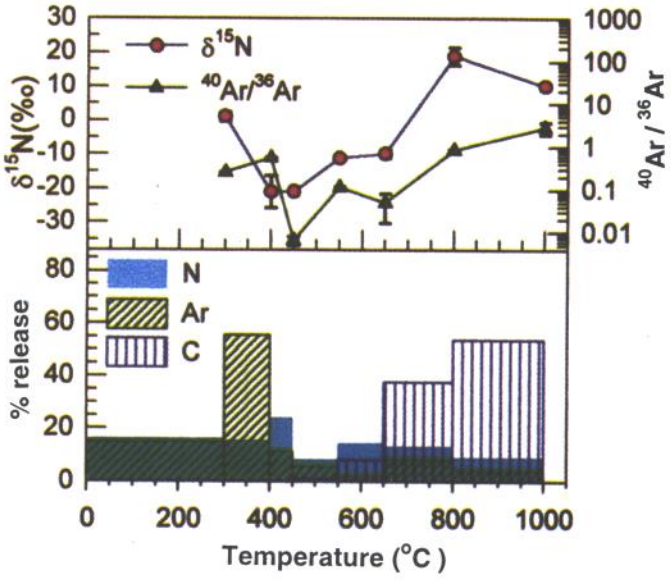

Fig.6.7 Release pattern of N, C, ^{36}Ar, $\delta^{15}N$ and $^{40}Ar/^{36}Ar$ for the HF/HCl residue of the diamond free ureilite ALH78019, by stepwise combustion.

and Portales Valley (H6 chondrite) that fell during the last four years were studied for cosmic ray produced noble gases (Ne, Ar and Xe) and radioactivity (^{54}Mn, ^{22}Na, ^{26}Al etc.). The radionuclide data are found to be consistent with GCR fluxes during the solar cycles 22 and 23. The chemical characteristics of the meteorites have also been established by neutron activation analysis.

A special low level shield for radioactivity measurements has been constructed using a large Hyperpure Germanium detector (115% relative efficiency) operating in coincidence/anti-coincidence with a NaI (Tl) well detector (**Fig. 6.8**). Extremeley low background and high sensitivity have been achieved and this system is capable of measuring small amounts of radioactivity produced by cosmic rays in meteorites. A multiparameter (Energy-Energy-Signal) system is being developed for this spectrometer.

The noble gas records from the Lohawat howardite have revealed very interesting information. Howardites are breccias and a good proportion of them have solar wind implanted noble gases. Our studies have shown that Lohawat is devoid of solar wind noble gases. More importantly the cosmic ray exposure duration of this meteorite is by far the longest (~100 Ma) for this class of meteorites. The achondrites, howardites (H), eucrites (E) and diogenites(D) are considered to have a common parent body. The exposure age of the Lohawat howardite suggest an impact event on the HED parent body that ejected this meteoroid into interplanetary space about 100 Ma ago. Alternatively this could be also the time of break up of a large HED parent body fragment in interplanetary space.

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

Isotope Geochemistry and Geochronolgy of Mantle and Flood Basalt Samples

Nitrogen in the Diamonds and MORB

The inventory of the volatile element nitrogen for planet Earth and its isotopic evolution in the atmospheric and internal reservoirs (mantle and core) is intimately related to the processes governing the accretion and subsequent evolution of the Earth. We have been investigating the mantle reservoir to understand its N systematics. Our earlier studies of mantle xenoliths have indicated the presence of recycled N-component in them. We have now extended this work and measured N and Ar in other mantle reservoirs (diamonds and mid ocean ridge basalt glasses). Diamonds from Africa and Australia and MORB glasses from Pacific and Indian oceans have been studied. The $\delta^{15}N$ values of these samples vary between +15 to -15‰, . The simultaneous study of N and Ar has helped in resolving the total mantle N into three components: a pristine mantle component ($\delta^{15}N \leq -15‰$), a component from air saturated water ($\delta^{15}N = 0‰$) and one from subducted sediments ($\delta^{15}N \geq 15‰$). The observed variation in $\delta^{15}N$ among mantle samples can be explained as due to the presence of a recycled N component, introduced into the mantle through subduction of ocean sediments. Our results point towards a ubiquitous presence of subducted N component in the mantle.

(R.K.Mohapatra and S.V.S.Murty)

Fig.6.8 A specially built counting system for assaying the very low level radioactivity produced by cosmic rays in meteorites

Ar-Ar Geochronology of Basalts, Dykes and Carbonatites

Determining the exact timing and precise duration of the Deccan volcanism still remains an important and debatable issue. The implications of this information to the models of flood basalts generation and the stratigraphic K/T Boundary (KTB) problems are immense. We have continued to work on the Ar-Ar geochronology of Deccan basalts to address these issues. This year we have obtained plateau ages of ~65 Ma for several Deccan basalt dikes, which show that the dikes are coeval with the Deccan tholeiites. We have also focussed attention on the volumetrically minor but petrologically varied magmatic rocks in the Deccan, such as the alkaline rocks and the carbonatites, and felsic volcanics. Carbonatites of the Amba Dongar alkaline province have yielded plateau ages of 65.4 Ma. The data reinforces our earlier findings that the Amba Dongar carbonatite-alkaline magmatism was coeval with the KTB and was an important factor in triggering the KTB events. Geochronological studies of felsic volcanics of the Deccan and also from St. Mary's Isles, to the south of Deccan are currently in progress.

(R. Bhutani, R. Jadeja, K. Pande, J. S. Ray, H. C. Sheth and T. R. Venkatesan)

Geochemistry of Alkaline Basalts from Kutch and Saurashtra

Deccan volcanism whose estimated total volume is ~$10^6 km^3$ represents one of the most extensive lava flows among the continental flood basalts . These basalts have been studied extensively for their chemical, mineralogical, palaeomagnetic and geochronological framework. Several flows exposed in the western Ghats (Ambenali, Igatpuri, Mahabaleshwar etc.) and north eastern province (Nagpur, Jabalpur, Salbardi etc.) have been studied in detail. However, except for a few samples, the flows from Kutch and Saurashtra region have not been studied. As we have found a K/T boundary in the intertrappean samples between these lava flows, a detailed geochemical and palaeomagnetic study was undertaken. Major, minor and trace element data indicate that most of these

basalts are alkaline in nature whereas majority of Deccan basalts are thoeiilitic. In various discrimination diagrams the Anjar basalts and the ocean island basalts group together. Further, several diagnostic trace element ratios (e.g. Sm/Nd, Ba/Nd, Y/Nb and Zr/Nb) are similar to Reunion Island basalt and suggest a Reunion Plume origin.

Paleomagnetic data indicate that three lava flows below the K/T horizon have a normal polarity whereas all except one of the upper basalt flows show a reversed polarity. The results suggests a few million year span for the Deccan volcanism, consistent with geochronological studies using $^{40}Ar/^{39}Ar$ carried out earlier in our laboratory. Some of the geochemical studies were carried out in collaboration with Dr.V.Balaram at National Geophysical Research Institute, Hyderabad.

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

Iridium and Other Noble Metals in Basalts and Carbonatites

An attempt has been made to measure simultaneously iridium and other noble metals such as Os, Ru, Ag etc. in a sample, without carrying out detailed radiochemical separation for individual elements. In this technique the neutron irradiated samples along with Ni powder, sulfur and appropriate fluxes are heated in a porcelain crucible at high temperature (~1100°C) for a few hours. On cooling a NiS bead is formed at the bottom of the crucible. This bead almost quantitatively extracts the noble metals from the samples and is counted on a Ge detector assembly for characteristic γ-rays of various platinum group isotopes to assay their concentrations. Preliminary studies on carbonatites and associated basalts which erupted around K/T boundary time (~65 Ma ago) show that the Ir concentration in these samples range from 10 to 70 pg/g which do not contribute significantly to the total Ir budget at the K/T boundary.

(P.N.Shukla, A.D.Shukla, A.Das, J.S.Ray and N.Bhandari)

Age of the Sylhet Traps, Eastern India

The smaller exposures of flood basalts - the Rajmahal and Sylhet traps - present in the eastern India have been

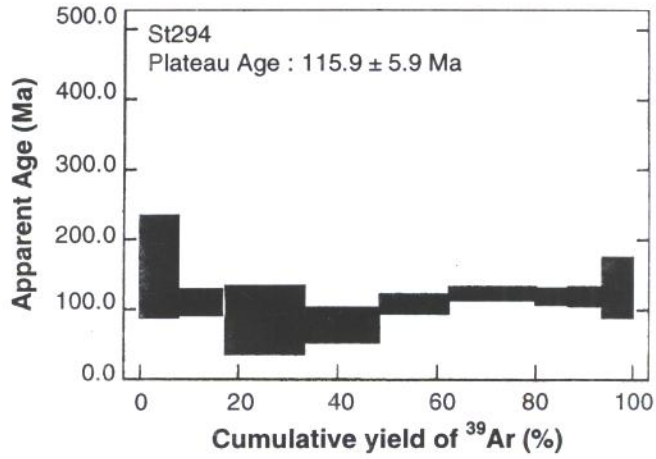

Fig.6.9 Ar-Ar age spectrum for the sample ST 294 of Sylhet traps.

ascribed to the separation of India from Antarctica during the breakup of Gondwana land. A genetic link between these basalts and the Kergulen hot-spot has also been hypothesised. While the Rajmahal traps have been dated earlier at 115 Ma, Ar-Ar plateau ages of 115.9±5.9 Ma, for the Sylhet Traps have become available for the first time from work done in our laboratory (**Fig.6.9**). This age make them coeval with the Rajmahal Traps, about 700 Km to the west, and strongly suggest that these two together comprise a single large igneous province. Carbonatites from the Sung valley region, geographically located between these two basaltic provinces, have yielded a plateau age of 107±21 Ma, and appear to be part of a late-stage alkaline pulse following the Rajmahal-Sylhet flood basalt volcanism. These ages are consistent with the hypothesis that the Sung Valley alkaline-carbonatite magmatism marks the end of Kergulen plume activity and the separation of India from Antarctica and Australia.

(R. Bhutani, R. Jadeja, K. Pande, J. S. Ray, H. C. Sheth and T. R. Venkatesan)

Uplift and Erosion Rates of the Tibetan Plateau

The importance of the tectonic uplift of the Tibet Plateau in modifying the global climate during the past few million years has been recognized, yet no reliable methods have been developed to date for measuring the rates of uplift of the plateau. We have now made first attempts to obtain quantitative lower limits to uplift rates during the

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 150 PCs and few work-stations distributed throughout the Laboratory. The system is also connected by a VSAT (Very Small Aperture Terminal) link to the INTERNET with a hub at Bangalore. In addition, this year it is also connected to the INTERNET via a fast wireless link. 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 and prints and video tapes is available. The centre provides the consultations and other facilities including archival of file systems, system security, authorisation, updating the sytem soft-wares, third party softwares and public domain softwares. It also maintains Internet connectivity and the local area network.

Library

PRL library consists of a rich collection of 16,000 books, 25,000 bound volumes of journals, reports, video cassettes, CDs, PRL publications like reprints and technical reports etc. Besides circulation of books, journals and documents, library provides services like photocopying, reference service, internet searching, SDI services, retrospecitve literature search, inter-library loan, translation etc.

During this year PRL library subscribed to 168 scientific and technical journals. In addition, the library receives large number of scientific reports, data, maps etc. During this year 270 books were added to the library collection.

PRL library has subscribed to two scientific databases namely STN and Uncover to get abstracts and full text articles from about 18,000 journals, which PRL library is unable to subscribe. The articles are received by FAX/ E-mail.

Under inter library loan as many as 400 requests were received for obtaining publications. Most of these requests were from outside, in which PRL library supplied the publication.

During the year more than 8000 books and journals were issued. About 4,50,000 photocopies were supplied to users using in-house facility as well as using outside resources.

PRL library maintains a home page http://www.prl.ernet.in/~library which provides complete and uptodate information about library resources and important links to other resources of interest to PRL scientific community. The home page provides links to about 56 subscribed journals available in electronic form.

Electronics Laboratory

Electronics Laboratory is carrying out research activities in the area of hardware implementation and software stimulation of Neural Network and Fuzzy Algorithms. Various algorithms are developed for dedicated high speed hardware, mircrocontrollers and DSP devices. Network based algorithms are developed for handwritten character recognition for walking robots and crime detection problems. The application programs are developed using JAVA for distributed parallel computing in heterogenous computing environments. A large feedback type neural network consisting of sixteen thousand neutrons and two hundred fifty six connections is developed to demonstrate reconstruction of face from the skull image.

About 30 B.E./MCA students from Engineering Colleges undertook their project work in Electronics Laboratory. They worked in the area of Image Processing, Advanced Computer Communication, Data Acquisition System, Fuzzy Controller etc.

PRL Lan is heterogeneous LAN and provides connectivity to more than 250 PC nodes and workstations using DOS, Windows and variants of UNIX OS. Internet applications for office automation were developed in C and Java by students/trainees.

The new CNC lathe machine installed at Workshop

Workshop

The workshop at PRL forms an important component of its experimental programme and is involved in a variety of development jobs and time bound projects. The existing facilities in the workshop include general purpose machine shop, drawing section and painting section. Upgradation of the workshop facilities both in terms of infrastructure and equipment is being made. A new CNC lathe machine (Model HMT ECONO 26) has been installed at the PRL workshop and is working satisfactorily. A portion of workshop has been renovated and air-conditioned to house the new CNC machine. Dressing, painting and store rooms have also been renovated. Three mechanics were sent to HMT Factory at Kalamassery, Cochin for training in the operation of the CNC machine.

Some of the important works carried out at PRL workshop are :

1. A lead shield for X-ray spectrometry to get low back ground for SOS/GE group has been designed and fabricated. This involved the heavy rigid structural fabrication work along with door, to in-house the sophisticated instruments like delicate crystals. A mechanism for lifting crystal inside the lead shield chamber has also been made.
2. Fabrication of multi-wavelength airglow photometer containing various mounts, lens assembly and filter wheel drive gear train for stepper motor type drive to be used for optical imaging (PLT-AS).
3. Designed and fabricated various mounts for Interference filters, Fabry-Perot etalon assembly, lens system for PLT-AS group.
4. Langmuir probes to be used in rocket have been fabricated for PLT-AS area.
5. Fabricated a Split Faraday Cup and Bragg Curve Spectrometer to be used in Accelerator Mass-Spectrometer Facility for Basic Physics Laboratory. This involved fabrication of small

critical components with close tolerance of 20 parts made from SS 304 material, SS chamber and high vacuum joints.

6. Developed and manufactured a peristaltic pump for OCE-CS group. Work related to modification of valves and bellows were also carried out.

7. A central fringe scanning unit was designed and fabricated at its Thaltej extension for AST-ASP group. It involved fabrication of some jobs, mounting and aligning of various optical components which includes lens, eye-piece, aperture, X-Y side, Fabry-perot, prism, PM tube and CCD. Some of the existing optical units were modified from manual to motorized mechanism. Servicing and repairing work related to telescope at Mt. Abu were also carried out.

In addition to the above, jobs related to high vacuum, miscellaneous jobs from different experimental groups were also completed. Few technical lectures were also arranged for workshop mechanics.

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. Right from the land acquisition to maintenance of all the residential and non-residential buildings and its related services for various campuses of the laboratory are handled. These includes architectural planning, designing, estimating and execution of various civil works and related services, landscaping, horticultural development, interiors and furnishings of buildings and structures of all the six campus-PRL main campus, Colony Campus, Thaltej Campus, Mt. Abu Campus, Udaipur Campus and Vikramnagar Campus.

Site Preparation works were executed for installation of sophisticated research equipments by meeting with all special requirements. During the year following major works were undertaken:

Modification of D type quarters for converting into International Hostels (Guest house Annexee).

Cement plastering works to PDF blocks and staff quarters.

RCC elevated overhead tank of 1 lakh litre capacity with 20M staging at Thaltej Campus, has been installed.

Addition and alteration work in Workshop for the installation of CNC lathe machine have been taken up.

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 J. C. Parikh

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 A C Das	Theoretical Plasma Physics, Space Plasmas	Ph D Imperial College, London Univ. (1968)
Prof S Krishnaswami FNA, FASc, FNASc	Aqueous Geochemistry and Nuclear Oceanography	Ph D TIFR, Bombay Univ. (1974)
Prof M R Deshpande	Astronomy and Astrophysics and Space Science	Ph D PRL, Gujarat Univ. (1968)
Prof A R Prasanna	General Relativity and Astrophysics	Ph D Poona Univ.(1970)
Prof Vijay Kumar	Experimental Atomic and Molecular Physics	Ph D Univ. of Adelaide, Australia (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	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. R Sridharan FASc	Upper Atmospheric and Ionospheric Physics	Ph D PRL, Gujarat Univ. (1984)
Dr D K Chakrabarty	Ion and Neutral Chemistry of Earth's Atmsophere	Ph D NPL, Delhi Univ. (1973)
Dr T R Venkatesan	Geochronology	Ph D Minnesota Univ. (1976)
Dr B G A Rao	Spectroscopic Diagnostic in Astrophysical Plasmas	Ph D PRL, Gujarat Univ. (1978)

Name	Specialisation	Academic Qualification
Dr S P Gupta	Electrodynamics of Middle Atmosphere	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)
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 (Miss) S L Kusumgar	Palaeoclimatology, Chronology	Ph D PRL, Bombay Univ. (1980)
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	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)

Name	Specialisation	Academic Qualification
Dr Ashok K Singal	Radio Astronomy	Ph D TIFR, Bombay Univ.(1986)
Dr A M Punithavelu	Experimental Plasma Physics	Ph D Patrice Lumumba Univ., Moscow (1975)
Dr D P K Banerjee	Astronomy & Astrophysics, High Resolution Spectroscopy	Ph D PRL, Gujarat Univ. (1991)
Dr K P Subramanian	Experimental Atomic and Molecular Physics	Ph D PRL, Gujarat Univ. (1987)
Dr Syed Aftab Haider	Planetary and Cometary Atmospheres	Ph D Banaras Univ. (1984)
Dr P Janardhan	Radio Astrophysics	Ph D PRL, Gujarat Univ. (1992)
Dr R Sekar	Upper Atmospheric and Ionospheric Physics.	Ph D PRL, Gujarat Univ. (1991)
Dr 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)


MOLECULES IN INTENSE FIELDS
FEBRUARY 15 - MARCH 7, 1999
PHYSICAL RESEARCH LABORATORY AHMEDABAD


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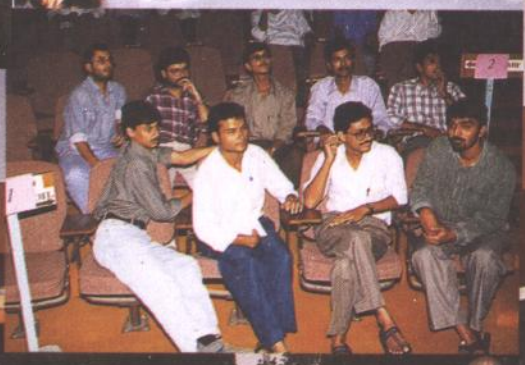
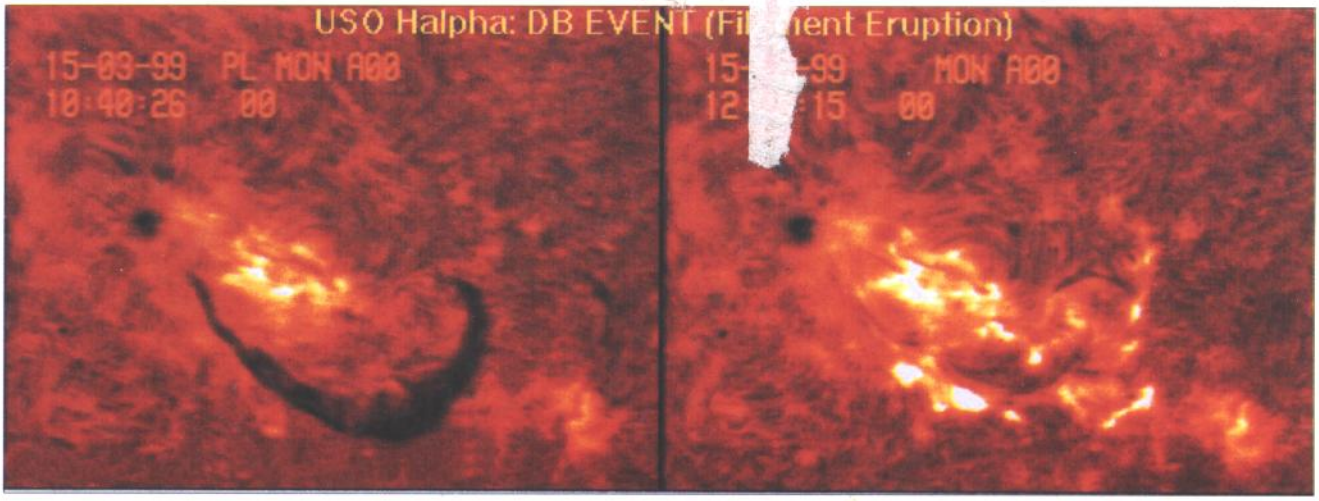
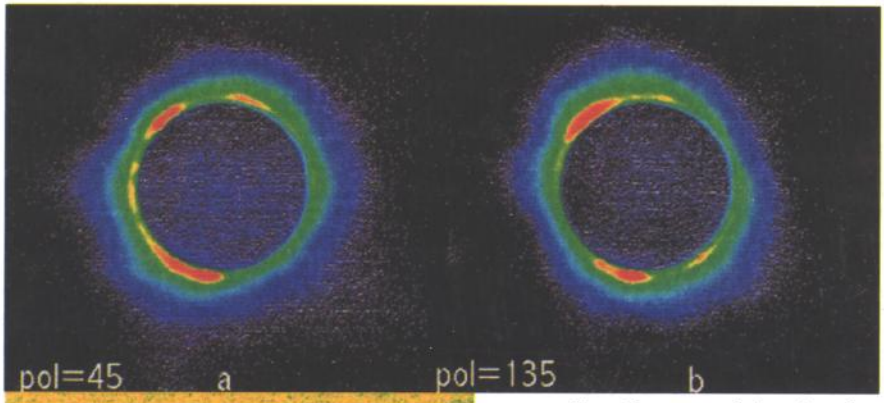




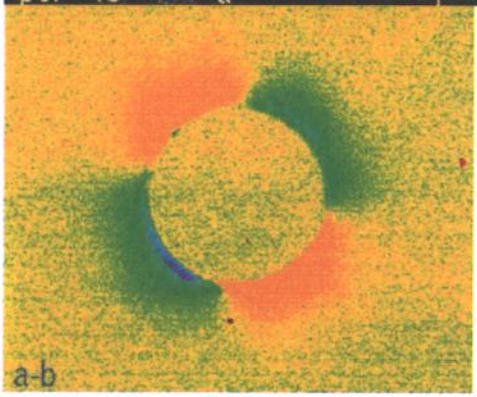
सूर्यधब्बा के निकट सघन व शीतल पदार्थ वाले दीर्घ काले ''तंतु'' का गायब होना । सूर्य के गुरुत्व व चुंबकीय क्षेत्र द्वारा इस पदार्थ का संतुलन रखा गया था । तथापि, इसके पड़ौस में निरंतर विकासक्रम व तीव्र परिवर्तन होने के कारण , यह संरचना अस्थिर हो जाती है व उद्‌भेदित हो जाती है, जैसा 15 मार्च, 1999/12:40 IST पर देखी गई थी । इस उद्‌भेदन की आकाशीय स्केल को सूर्यधब्बा के आकार से तुलना करके मापा जा सकता है, जो हमारी पृथ्वी के आकार के बराबर है । ये उद्‌भेदन घटनाएं अन्तरग्रहीय अंतरिक्ष में काफी पदार्थ फेंकती हैं तथा सौरतंत्र के मौसम को प्रभावित करती हैं ।

Disappearance of a large dark "filament" containing denser and cooler material near a sunspot. This material was kept in balance by the sun's gravity and magnetic field. However, due to continuous evolution and rapid changes occurring in its neighbourhood, the structure suddenly got destabilised and erupted as seen at March 15, 1999/12:40 IST. The spatial scale of the eruption can be gauged by comparing the size of the sunspot, which is nearly as big as our earth! These eruption events pump large quantity of material in the interplanetary space, and affect the solar-system weather.

पूर्ण सूर्य ग्रहण AUGUST 11, 1999 TOTAL SOLAR ECLIPSE



इस्फहान, इरान से यूएसओ-पीआरएल टीम द्वारा लिए गए पूर्ण सूर्यग्रहण बिंब । ये बिंब व्यतिकरण फिल्टर (6993 A, FWHM 80 A), (a) 45 डिग्री, (b) 135 डिग्री की तरफ झुके पोलरोइड अक्ष से लिए गए थे । ~2.2x2.2 दृश्य क्षेत्र के लिए f/12,642 mm लेंस प्रणाली व एक कूल्ड 1024 x 1024 CCD कैमरे का उपयोग किया गया । बिंब में अंतर (a-b) किरीट से ध्रुवित प्रकाश का तेज़ दृश्य दर्शाता है ।



इस्फहान में 1 मिनट 33 सेकंड की पूर्णता के दौरान यूएसओ टीम ने निकट प्रतिबिंब भी प्राप्त किए । इन फिल्टरों के संकीर्ण पास बैंड ने प्रेक्षित फ्लक्स को सीमित किया, व केवल निकट किरीट का ही बिंब लिया जा सका ।

(a) व (b) में चटकीला लाल उत्सर्जन प्रक्षेपों के स्थलों से सहसंबंधित है ।

Total Solar Eclipse Images taken by USO-PRL Team from Isfahan, Iran. Images were taken through an interference filter (6993 A, FWHM 80 A), polaroid axis positioned at a) 45 deg, b) 135 deg. An f /12, 642 mm lens system, and a cooled 1024x1024 CCD camera was used for imaging a field-of-view ~ 2.2x2.2 degrees. The difference image (a-b) shows a quick view of the polarized light from the corona.

During the 1min 33 sec of totality at Isfahan, near IR images were also obtained by the USO team. The narrow passband of the filters limited the observed flux, and only the near corona could be imaged.

The bright red emission in (a) & (b) correspond to location of prominences.