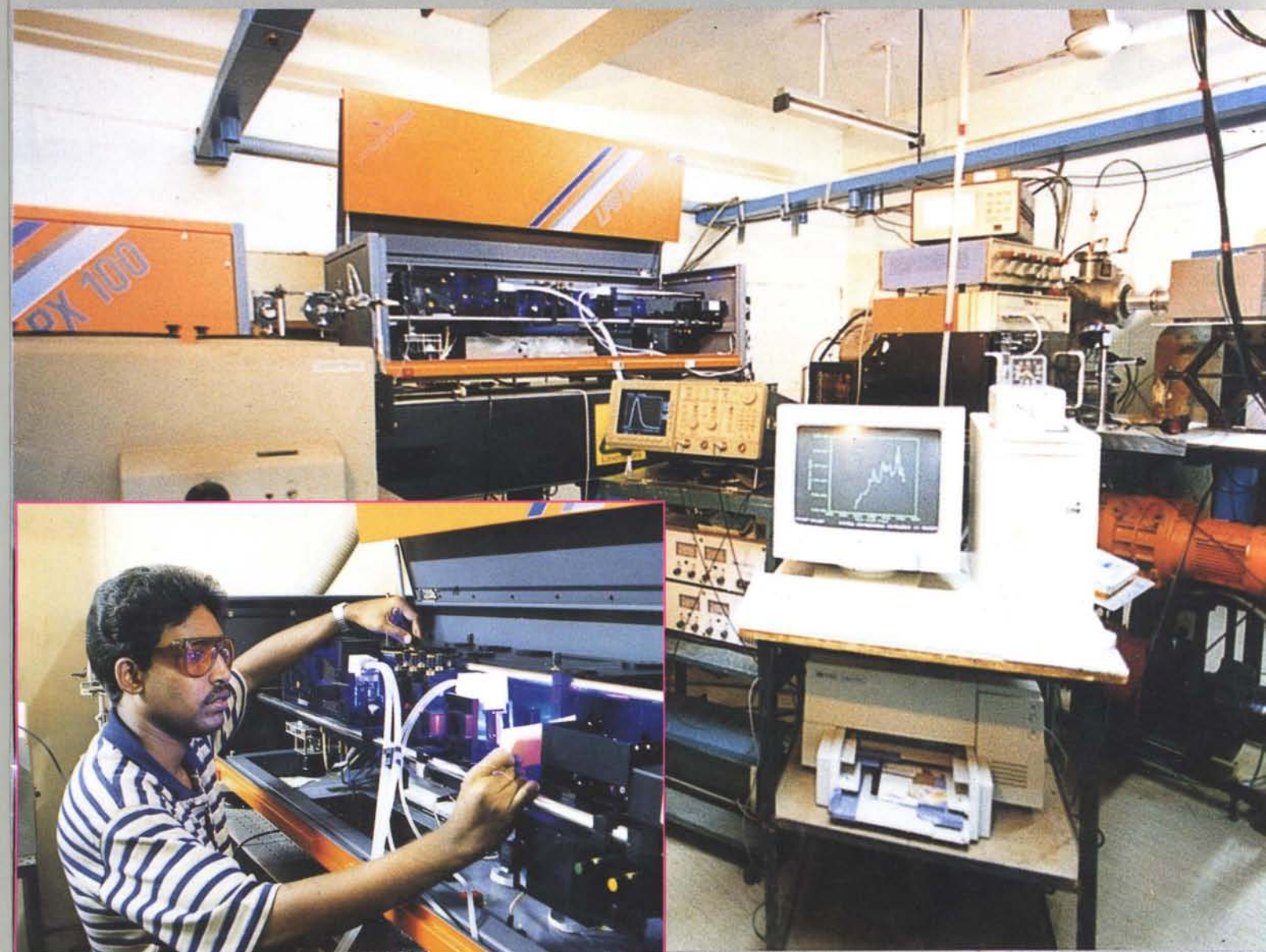


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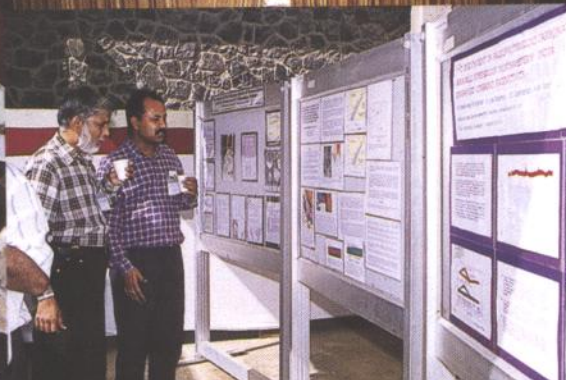
Physical Research Laboratory, Ahmedabad

वार्षिक रिपोर्ट

Annual Report 1997-98











भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद  
Physical Research Laboratory, Ahmedabad

वार्षिक रिपोर्ट  
1997- 98  
Annual Report

*Front Cover :*

*Laser Laboratory for carrying out Atomic Physics experiments.  
Excimer-laser tuned dye-laser is shown in the picture.*

*Inner Front cover :*

*Glimpses from the conferences/symposia held at PRL  
as a part of the Golden Jubilee celebrations.*

*Inner Back Cover :*

*Glimpses from Popular Lectures, Hindi Week Celebrations  
and the National Science Day celebrations.*

*Back Cover :*

*Starburst Galaxy - Mrk332 - where tidal interaction with  
a neighbouring galaxy is evident.*

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The year 1997-98 was a very active period for the Physical Research Laboratory. Till December 1997 the laboratory continued different scientific activities to celebrate its Golden Jubilee year. The laboratory completed its fiftieth year on November 11, 1997. Today PRL is amongst the very few premier institutes which has a multidimensional research programme encompassing disciplines like astronomy and astrophysics, planetary and space sciences, earth sciences, theoretical physics and laser physics and quantum optics. The laboratory has strengthened its research programme in nonlinear dynamics and computational sciences.

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 twenty one papers have been published, of which one hundred and six were in high impact journals. During the year our scientists have convened seven symposia/workshops, one of which the International Conference on Isotopes in the Solar System was organised at PRL. Also our scientists continued to participate actively in national and international conferences with large number of invited and contributed presentations. During the reporting year two hundred and thirty papers were presented out of which seventy eight were invited review talks and eighty three were presented in international conferences. A summary of scientific achievements is given on page 5.

The laboratory's contribution to basic research in various fields has been recognised both nationally and internationally. Some of our scientists have been honoured by a number of prestigious national and international honours and awards such as the prestigious *Rathindra Puraskar* by the Visva-Bharati University, Shantiniketan; *MP Birla Memorial Award 1997*; *Humboldt Research Award* by the Alexander von Humboldt Foundation and the *Indian National Science Academy Medal for Young Scientists*.

The laboratory had strong participation in various international and national programmes. Our scientists are participating in two programmes under the International Geological Correlation Programme (IGCP): (i) to understand the response of the ocean/atmosphere to

past global changes and (ii) to understand future dryland environmental changes from past dynamics. A programme on Trace Gases in the Atmosphere is also being actively pursued under the International Atomic Energy Sponsored Programme. A project on Meteorites and the Early Solar System is being carried out under an agreement with the Department of Science and Technology, India and the Russian Academy of Sciences. Recently a project on studies of Lunar Samples and Meteorites has been approved by the Department of Space, India and NASA, USA. Our collaboration in Global Oscillation Network Group and Indian Ocean Experiment (INDOEX) is continuing and data analysis is under progress. On the national front besides the Joint Global Ocean Flux Studies (JGOFS) and the Geosphere Biosphere Programme of ISRO (ISRO-GBP) we are actively associated with programmes like Land Ocean Interaction in the Coastal Zone (LOICZ), Chemical Studies of Himalayan Glaciers, Indian Solar Terrestrial Energy Programme (ISTEP) and All India Coordinated Programme for Ionosphere -Thermosphere Studies.

**Prof. Govind Swarup**, FRS, Professor Emeritus, TIFR visited PRL as the twentieth Vikram A. Sarabhai Professor. During his visit he gave four lectures and a popular lecture on *Are We Alone in the Universe ?*. **Dr. S. K. Joshi**, Vikram Sarabhai Research Professor, NPL delivered the eleventh Prof. K.R. Ramanathan Memorial Lecture entitled *Superconductivity : Fountainhead for New Technologies*. **Dr. R. Chidambaram**, Chairman, Atomic Energy Commission and Secretary, Dept. of Atomic Energy delivered the twelfth Prof. K.R. Ramanathan Memorial Lecture entitled *R&D Challenges in Nuclear Technology*. In addition, many other distinguished scientists visited the laboratory.

The **Golden Jubilee Year celebrations** of the Laboratory which began on November 21, 1996 continued till December 1997. As a part of the celebrations, a large number of seminars, symposia, conferences were organised. A four-day **International Conference on Isotopes in the Solar System** was hosted by the laboratory during 11-14 November, 1997. More than sixty scientists from twelve foreign countries along with more than a hundred scientists from India participated in the

deliberations of the conference. The focal themes discussed in the conference included formation of the solar system, evolution of the planet Earth and its past climatic history and the chemistry and dynamics of the river-ocean system. New results obtained from the study of isotopic records preserved in samples of meteorites, terrestrial rocks, sea sediments, ice cores, glaciers, corals, cave deposits and in rivers, oceans and ground waters that have direct bearing on the focal themes were also presented. An evening lecture on *Unveiling the Mystery of Mars* by **Prof. T. D. Swindle** was also arranged.

**A conference on Nonlinear Dynamics and Computational Physics** was held at PRL during November 18-22, 1997. The conference had over seventy participants of which about half were from outside of PRL. There were also a number of participants from France, Belgium, Germany, UK and the USA. The conference dealt with a few broad subjects namely chaotic quantum systems, statistical mechanical aspects of chaos, three body Coulomb problem in quantum mechanics, laser driven helium, random matrix theories, chaos in plasma physics, chaos and pattern formation, spatio-temporal chaos and time series analysis. Several of the papers presented at the meeting highlighted the role played by computers in the discovery and in the elucidation of physical phenomena in complex systems.

As a part of the Golden Jubilee year celebrations of PRL, the **10th National Space Science Symposium** was organised at PRL from November 25-28, 1997. About three hundred space scientists from different research institutions and universities in India participated. The symposium covered wide range of subjects such as cosmic-rays, astronomy-astrophysics, physics of the middle atmosphere, ionosphere-thermosphere-magnetosphere, remote sensing, space meteorology etc. There were three special, topical, plenary sessions on Space based Observations for Atmospheric Modelling, Global Coupling Processes in Ionosphere-Thermosphere System and Frontiers in Astronomy. In addition to the twenty seven invited talks by leading scientists in their respective fields, there were about two hundred contributed papers. An evening lecture on *Current Ideas on the Origin of the*

*Universe* by **Prof. J. V. Narlikar** formed part of the symposium.

**The XVIII Annual Meeting of the Astronomical Society of India** was hosted by PRL from November 28 to December 1, 1997. It happened to be the Silver Jubilee Year of the ASI. More than two hundred astronomers and astrophysicists from all over the country took part in the deliberations spread over three and half days. The scientific programme of the meeting covered all the aspects of astronomy and astrophysics varying from Sun and solar system to galactic and extragalactic astronomy, structure and evolution of stellar systems, pulsars, satellite astronomy, cosmology, instrumentation and new techniques in data analysis. A total of thirty invited talks and one hundred twenty contributed papers were presented. In addition two evening lectures on *The History of Astronomy in Asia in the Medieval Period* and *The HST Revolution* were delivered by **Prof. S. M. R. Ansari**, Aligarh Muslim University and **Prof. K. D. Abhyankar**, Osmania University respectively.

**A symposium** covering different aspects of **Lasers and their Applications** was held during December 10 - 12, 1997 at PRL under the auspices of the National Laser Programme. The technical programme of the symposium included invited talks by leading scientists from India and abroad, poster presentations of original work in the field of lasers and their applications, and oral presentations of thesis work by young researchers who had submitted their theses. The topics covered were physics and technology of lasers, laser spectroscopy, ultrafast phenomena, nonlinear optics, quantum optics, laser plasma interaction, laser materials, applications of lasers in biology and medicine and laser-based instrumentation and industrial applications of lasers. The symposium was attended by about three hundred delegates presenting more than two hundred papers. The programme also included two evening lectures on *Bose-Einstein Condensation* and *Gravitational Waves* by **Drs. D. D. Bhawalkar** and **Jürgen Ehlers** respectively.

With a view to increase the interaction between science colleges in Ahmedabad and PRL, PRL hosted a **series of lectures** by members of different groups at **PRL for Physics college teachers** from March 30 - April



3, 1998. The lectures were designed to give the participants an overview of the research carried out by the faculty at PRL as well as to introduce them to specific projects at PRL where they could participate. It is hoped that these lectures will lead to short-term or long-term collaborations in future.

A five - day course on **Laser Physics, Laser Techniques and Non-linear Optics** was given to the M.Tech. students of Devi Ahilya Vishwa Vidyalaya (DAVV), Indore during March 30 - April 3, 1998. The course was designed to expose the students to the frontiers of Laser Physics, Laser Techniques and Quantum Optics. Five students and one faculty member of DAVV attended the course comprising of sixteen lectures covering topics in non-linear optics and laser techniques, laser propagation through atmosphere and high resolution laser spectroscopy.

As a part of implementation and progressive use of Hindi in PRL, the **Hindi Week** was celebrated at PRL from September 15 - 21, 1997. The special attraction of this year's celebration was lectures by two eminent personalities - one by **Prof. Ramlal Parikh**, Vice Chancellor of Gujarat Vidyapeeth, who gave the opening lecture, and the other by **Prof. K.S. Valdiya**, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, who gave a very interesting talk on *Neotectonic Activities in North Western India*. In addition, during the year a few cultural programmes on classical and folk dances of India and classical music were organised for the participants and staff members.

The **National Science Day** was organised on March 1, 1998 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, science exhibition including experiments and exhibits and video shows formed part of the programme. The science quiz was open to students of standards IX to XI from schools all over Gujarat. One hundred and fifty two students participated in the written science quiz. To foster scientific temperament, all the participants in the science quiz were presented with popular science books by INSA Ahmedabad Chapter. The IPA, Ahmedabad Chapter has provided a year's subscription of Science Reporter in English and Hindi to all the participants. In addition, Physical Research Laboratory presented microscopes to top six secondary and twelve higher secondary students in 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. Five students were selected for **PRL Scholarship** from the Aruna Lal Endowment Fund established by Prof. D. Lal, Honorary Fellow and former Director of PRL, on the basis of their performance in Science Quiz organised during the National Science Day and personal interview, held to judge the student's scientific aptitude and motivation for doing science.

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.

GS Agarwal

Director

**PRL  
in a  
Nutshell**



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

- i. Theoretical Physics;
- ii. Laser Physics and Quantum Optics;
- iii. Astronomy and Astrophysics;
- iv. Planetary Atmospheres and Aeronomy;
- v. Earth Sciences and Solar System Studies.

The chart below profiles the scientific activities.

Some of the important research contributions are summarised.

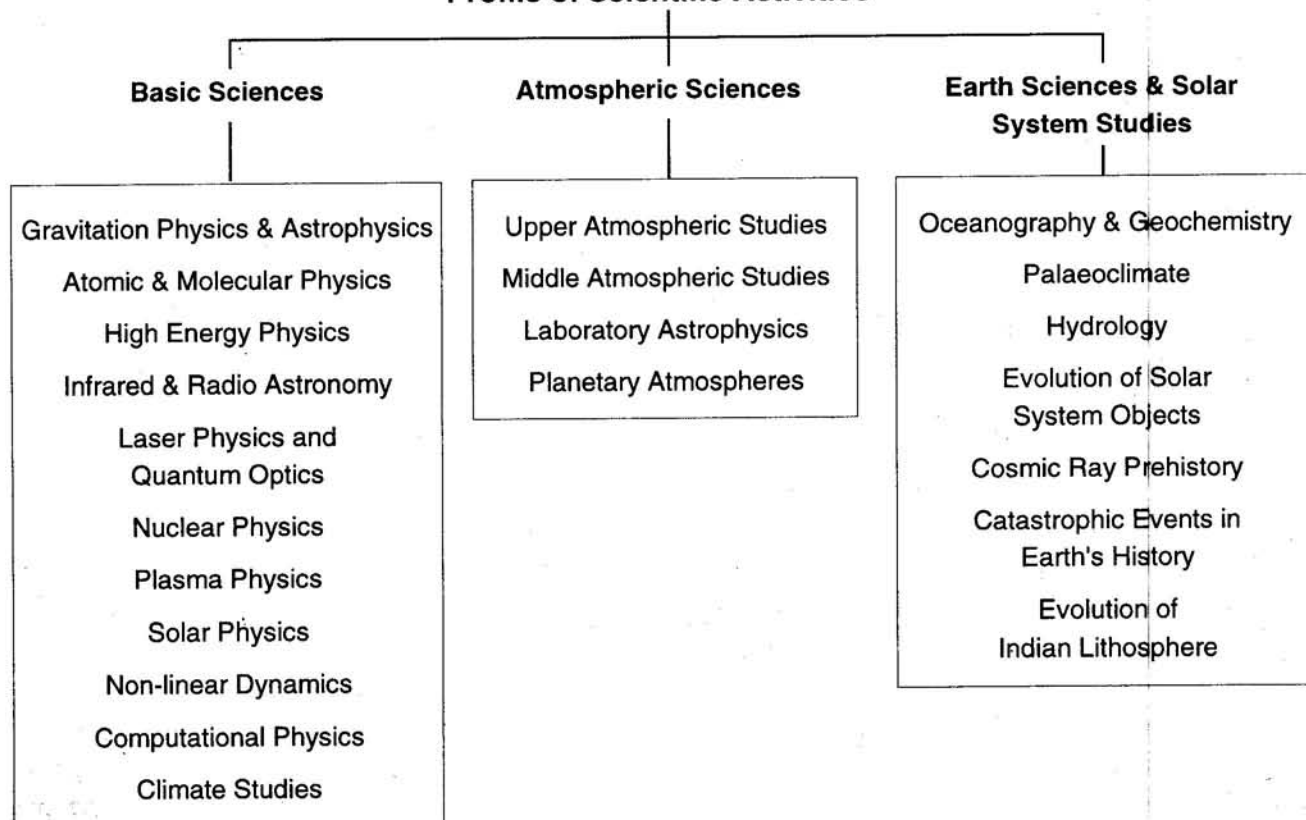
## Astronomy and Astrophysics

The scientific work of the Astronomy and Astrophysics Division covers the solar physics, interplanetary medium, cometary physics, star formation, stellar evolution, star burst galaxies and active galactic nuclei. To carry out these research programmes variety of instruments were designed and developed in-house. To understand the basic physical processes, modelling work is being carried out.

The Astronomy and Astrophysics Division is located in Thaltej Campus (7Kms from PRL). A 1.2m IR telescope is operational at Mt. Abu. A Solar Observatory (USO) is located at Udaipur. Both the observatories are equipped with modern instruments, most of them indigenously developed. This year, a state of the art instrument - IR array has been added. This has enhanced the capability of the IR telescope. At USO, GONG experiment is being operated to study the solar interior using helioseismology.

During July-September 1997 giant radio bursts were detected on several days from a pulsar 0950+08. Such a high bursting activity sustained over a period of six weeks have not been reported earlier. Another significant finding was the direct detection of radio pulses from the Geminga pulsar. A lunar occultation of a Mira Variable R Leo was, for the first time, successfully recorded at 3.36 microns and its angular size was estimated ( $35 \pm 4$  milli arcseconds).

## Profile of Scientific Activities



Time variability studies of the Active Galactic Nuclei were continued. Coordinated observations at optical (PRL Polarimeter) and gamma rays (BARC) were conducted at Mt. Abu and simultaneous burst activity was detected in MRK 501. Such observations are very rare and will be very valuable to understand the nature of the central engine.

A sample of star burst galaxies was observed to detect star forming regions. The sample encompassed galaxies of different morphologies. It has been found that the enhanced star formation is not always confined to the nuclear region but it is also found to occur at the ends of bars or at the location of the resonances in barred spirals.

Dust condensation episode was detected through the IR observations in Sakurai's peculiar variable star after it went through a final helium shell flash. The temperature and the dust mass were calculated. Polarization observations indicate that this star has two components. The studies of Planetary Nebulae and Post AGB stars were continued. In addition to observations, a simple hydrodynamical model was developed to explain lower expansion velocity for the contact binaries compared to other class.

Photometric and spectroscopic studies on the molecular cloud complex in the region of Cassiopeia and Ophiuchus have been initiated in the near infrared using the NICMOS 3 camera. These observations will be crucial in understanding the star formation processes in giant molecular clouds.

To study the dust and gas properties of comet Hale Bopp imaging polarimetry was carried out encompassing  $7^\circ$  of field. High degree of polarization (up to 40 per cent) were detected in the jet. Strong wavelength dependence of polarization at various phase angles were also detected. Modelling work was carried out to explain the observations. The outcome of the modelling work indicates that finer grains were present in the tail region of the comet.

Ammonia was detected in comet Hale-Bopp using 100m radio telescope at Bonn. The temperature of Ammonia was estimated to be  $104 \pm 30\text{K}$  and a production

rate at perihelion of  $6.6 \pm 1.3 \times 10^{28} \text{ s}^{-1}$ . Also a marginal detection of water at 1.35cm was made.

At the Udaipur Solar Observatory, various studies of the Sun were continued. A significant progress has been made in the analysis of GONG data towards the understanding of helioseismology.

The solar flare of May 12, 1997 was studied at multiwavelengths (optical, X-rays and radio) in conjunction with magnetic fields. It was found that in this active region discrete but regular magnetic field variations in terms of emerging flux were occurring. Large photospheric flux motions were found which might have provided the magnetic energy storage for this flare, while the emerging flux region provided a trigger for the release of the stored energy. The effects of this flare were observed in the interplanetary medium and ionospheric D region. A model to explain the observations in terms of plasma motion has been proposed in which the hot plasma of  $10^7\text{K}$  evaporates the chromosphere.

Usually strong magnetic fields, gradients, electric currents and shear are associated with the location of large flares. However, the flare of September 29, 1991 occurred in a site of weak magnetic fields and low shear. The filament showed a significant amount of preflare activation as seen from the Chromospheric H-alpha observations. The observed transverse magnetic field azimuths exhibited rapid changes. It is suggested that these changes ultimately led to the destabilization of the filament and the energy stored in the sheared filament was fed to the flare.

The Division has made significant contributions towards the development of instruments this year. A two channel photometer for Lunar occultations, a fibre fed grating spectrograph, a near IR polarimeter and a wide field imaging polarimeter were developed. Improvements in the 1.2m IR telescope are also being made.

## Theoretical Physics

The researches performed by the Division cover wide ranging topics in atomic and molecular physics, gravitational physics, high energy physics, nuclear physics



ics, plasma physics, non-linear dynamics and computational physics. Some scientific achievements of the division are briefly highlighted below.

In gravitational physics, the external and internal structures of the magnetic field of a slowly rotating neutron star having matter with different equations of state are analyzed. It has been found that the increase in the field strength from surface to core is quite large (upto 30%) in the rotating case as compared to the non-rotating case. In the studies related to numerical relativity, the cactus code has been used to study the evolution of a system consisting of a Schwarzschild black hole and Brill type gravitational wave, in which the outgoing modes have been found to be predominantly quasi-normal modes.

In atomic and molecular physics, a compact expression of the form factor for transition between two arbitrary circular states is obtained which contains just one Jacobi polynomial. For the optically connected ( $\Delta_l = n_f - n_i = 1$ ) states, the formula reduces to a simple expression containing the associated Legendre polynomial  $P_{ni}^1$ .

In high energy physics, the implications of an experimental discovery at DESY in Hamburg of a new particle "leptoquark", which carries the lepton as well as baryon numbers, on supersymmetric theory were examined. It was suggested that modifications are needed in the minimal and commonly accepted version of the supersymmetric theory in order that it accommodated leptoquarks. In an ongoing study of possible signatures of CP violation in accelerator-based physics, the possible ways for finding chromoelectric dipole moment of top quark were suggested.

In the work done by the nonlinear dynamics and computational physics group, a new technique that combines linear feedback with adaptive control was introduced for estimating unknown parameters employing knowledge of only one time series. In the continuing study of chaotic quantum systems the emergence of the micro-canonical ensemble was analysed using both dynamical systems as well as random matrix theory. One of the first calculations in the world of spectra of three dimensional chaotic anharmonic oscillator systems were carried out and analysed.

In nuclear physics, it is shown that one of the symmetry schemes of a boson model, in which the bosons carry spin and isospin degrees of freedom, generates even-even and odd-odd staggering in the number of nucleon pairs coupled to isospin zero in the ground states of  $N=Z$  nuclei. For these nuclei, new types of spectra depending on spin and isospin are predicted.

In an investigation of dust-acoustic wave (DAW) propagation in a non-ideal classical dusty plasma, it is shown that the phase velocity of DAW gets modified according to the specific parameter that characterises the non-ideal nature of dust component. For large amplitude, super-sonic solitons seem to exist for both sub and super critical parameter regime while subsonic propagation is possible only for super critical case. A study of the propagation of nonlinear Langmuir waves in a bi-Maxwellian plasma has demonstrated the existence of a new class of Langmuir envelopes consisting of two nodes and a triple-hump structure in the field intensity.

## Laser Physics and Quantum Optics

The research output of this division has been mainly theoretical (although many of them do have experimental ramifications) with major emphasis on nonlinear quantum dynamics and optics, optical manipulation of atoms and quantum interference. Important contributions from this division involve the study of coherent structures such as Schrödinger cats and the quantum phenomenon of revival, development of a *quantitative* model for mode hopping in optical parametric oscillators, generation of squeezed light in quasi-phase matched medium, enhancement of nonlinear optical signals, new techniques for pulse shaping and control, collective oscillations in binary Bose condensates, vacuum induced coherence and its impact on coherent population trapping, laser-field induced quantum beats and a method for reconstructing the quantum state of a system of atoms or spins. These topics are summarized as follows.

Schrödinger cats are superpositions of macroscopically distinct quantum states and can be generated by nonlinear interaction, such as when a coherent state of the electromagnetic field propagates through a Kerr medium. But the concept of Schrödinger cat states is not

confined to electromagnetic fields only. It has been shown that cat-like states can also be generated for a system of two-level atoms in a dispersive cavity. These atomic cat states are superpositions of atomic coherent states and are produced by an effective interaction which is non-linear in the operator for atomic population inversion.

Almost all explicit calculations reported in the literature on Schrödinger cats and revival deal with systems whose energy spectrum depends on a single quantum number. In reality, many systems exist whose energy levels depend non-linearly on at least two quantum numbers. Consequently, their revival is governed by two time scales. We have provided a general theory to explain the complex revival structure of these systems and showed by means of explicit analytical results that the revival features and the formation of cat-like states are crucially dependent on the ratio of these time scales and on the symmetry of the initial wave packet. The dynamics of revival is rather delicate and is vulnerable to perturbations in realistic situations which are being studied in depth.

There have been a number of proposals for the reconstruction of the density matrix for harmonic oscillator systems such as the radiation field. Very little has been done on other systems. A new reconstruction procedure is proposed for a spin system with an arbitrary spin value. Since many systems (such as a collection of two-level atoms, or light which is polarized) can be described as a spin system, this scheme will be very relevant to a number of systems in quantum optics and in other fields.

One of the cherished goals in nonlinear optics is to find an ideal source of tunable radiation. Doubly resonant optical parametric oscillators almost fit the criterion if only large frequency instabilities due to mode hopping can be eliminated. The difficulty was accentuated by the fact that the phenomenon of mode hopping was understood only qualitatively. A quantitative model has now been developed in which the pump produces two pairs of signal-idler modes. Parametric oscillators can also be used for the production of squeezed light which has important applications in high precision interferometry and spectroscopy. It has been found that the efficiency is even higher if the non-linear medium is quasi-phase matched.

Tailor-made pulses are much in demand for communications, study of ultrafast processes and preparation of atoms and molecules in desired quantum states. A new technique for control and shaping of optical pulses have been demonstrated through an investigation of the dynamics of solitons in three-level atoms. It has been shown that solitons can be cloned, dragged and parametrically amplified in a coherently driven non-absorbing system.

Finally, in the wake of recent experimental realization of binary Bose condensates, their collective excitation was studied theoretically. It is shown that for pure binary-phase condensates, the excitation frequencies in an axially symmetric trap can be obtained from those of a single-component condensate by a simple scaling.

## **Planetary Atmospheres and Aeronomy**

The division's research programme continue to be related to the physical and chemical processes in the atmospheres of Earth, other Planets and Comets. These investigations are based on a variety of experiments on balloon, rocket and ground based measurements of the different atmospheric parameters, and also by formulating empirical and analytical models. The three broad classifications are middle atmospheric physics, upper atmospheric physics and laboratory astrophysics.

In the middle atmospheric physics, one of the major international coordinated programme Indian Ocean Experiment (INDOEX), got underway with the first field phase measurements carried out during February-March, 1998. These measurements extended to the south of the intertropical zone and revealed the presence of a cleaner environment along the cruise track. Quantification of the negative radiative forcing due to the aerosols has been made and found to be  $-13 \text{ W/m}^2$  for every 0.1 increase in optical depth over mid Indian ocean and an average  $-5.2 \text{ W/m}^2$  closer to the coastal area, much larger than the average  $-1.1 \text{ W/m}^2$  for the northern hemisphere suggesting transport of carbonaceous particles in addition to sulphates to the ocean from the land mass. The middle atmospheric dynamics programme of the division has got a boost with the full fledged commissioning of the *Rayleigh Lidar* from Mt. Abu. The lower altitude limit got further



lowered to ~ 3 km by facilitating the detection of the Raman scattered signals by  $N_2$  molecules at 607 nm for the incident 532 nm. Long term trends in ozone for the Indian stations revealed an increasing trend except over Varanasi where it was found to be opposite and this has been interpreted to be associated with the neutral dynamics in the form of a reverse Hadley Cell. On the other hand, middle atmospheric electrical conductivity showed a solar cycle dependence increasing by a factor of 1.5 during high solar activity. Surface measurements of ozone from the coastal areas (Trivandrum) in collaboration with Space Physics Laboratory, revealed unexpectedly the diurnal pattern similar to the industrial areas, in addition to showing the effect of the wind reversals during the day.

In the branch of upper atmospheric physics, a plausible explanation based on chemical heating and ion drag, for the recently discovered phenomenon of equatorial temperature and wind anomaly was provided and the effects of such local and nonlocal sources have been parameterized and successfully incorporated into the MSIS model. Daytime mesopause rotational temperatures from Kolhapur, by the unique multiwavelength daytime photometer revealed the deficiency of the present day models and also large scale variabilities. The dayglow measurements also revealed the possible effect on the lower thermosphere during *space weather* events like geomagnetic storms.

A major national level campaign conceived and coordinated by PRL was successfully completed during March-April this year as a part of the activities of the WG-3 on Ionosphere- Thermosphere studies of the Indian Solar Terrestrial Energy Programme, to investigate the role of neutral parameters and dynamics in the evolution of equatorial spread- F (ESF) with active participation of several national institutes and university groups. A variety of experiments like the Fabry-Perot spectrometers, dayglow photometer, all sky imaging cameras, VHF backscatter radars, MST radar, HF Doppler radar, ionosonde, VHF and UHF scintillation receivers, whistler monitoring systems etc. were operated making it one of the largest ever attempted studies. The first phase of the campaign had been a grand success and detailed data analysis has been initiated. The characteristic features of

the large scale plasma bubbles in the equatorial region were delineated using All Sky Imaging Photometry. Further estimation of the growth rate of irregularities using rocket-borne insitu measurements and assumed model parameters showed a good agreement with the region of maximum growth rate and the presence of irregularities. These measurements also revealed a new type of irregularity around 165-175km of 15 m - 1km scale sizes, calling for a new causative mechanism to be invoked. Simultaneous measurements of electron density and electric field fluctuations have shown that the former is anticorrelated with the vertical component of the latter below and above the base of the F-region and correlated at the base. Studies on the equatorial electrojet have revealed longitudinal inequalities in the same and these have been explained on the basis of the background electron densities. On the other hand, nonlinear numerical simulation studies have demonstrated the possibility of wind/temperature disturbance to act as a fresh source of instability and the otherwise confined irregularities now could act as a pre-seed and enable the resurgence of a *plume*. Studying the role of molecular ions in the evolution of a plasma bubble revealed that the growth of the irregularities above the base of the F-region mainly depends on the electron density gradient. However, for a two constituent medium it gets reduced. In another modelling front, on one hand, the data from the Phobos-2 Martian Space Craft, on hydrogen and helium ions has been explained by accounting for the escape of these ions by nonthermal processes i.e., due to polar wind acceleration processes, and on the other Viking 1 and 2 spacecraft results have been explained by accounting for magnetic diffusion as an effective loss process.

In the other major activity of the division, absolute electron scattering cross section for nitrous oxide and carbon monoxide at low electron energies have been determined in the laboratory and found that the differential cross sections in the case of polar molecules are larger than for the non polar ones. Fluorescence and lifetime studies on  $NO_2$  have also been carried out successfully using high power lasers in the wavelength range of 399-416nm and the effect of collisional quenching has been determined by conducting experiments at different pressures for both  $NO_2$  and  $SO_2$  molecules.

## Earth Sciences and Solar System Studies

The two areas, Oceanography and Climate Studies and Solar System and Geochronology, of this division continue to pursue programs in ocean circulation, palaeoclimates, evolution of solar system objects and the Indian Lithosphere and catastrophic events in Earth's history.

The application of Speleothem, a cave calcite deposit, to provide high resolution palaeoclimatic information over the past few millennia has been exploited. Samples from the Gupteswar cave, Orissa and the Dandak cave, Madhya Pradesh show remarkably similar temporal variations in their  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$ , though they are spatially separated by ~ 100 km. These data have been used to reconstruct the monsoon rainfall for the past ~ 3.5ka, which shows fluctuations of  $\pm 22\%$ .

The long term (several hundred millions of years) variations in the atmospheric  $\text{CO}_2$  concentrations has been a topic of investigation among geochemists to understand and quantify the processes controlling its budget in the atmosphere and associated global change. Carbon isotope composition of palaeosol carbonates provide means to obtain  $p\text{CO}_2$  of the atmosphere at the time of their deposition. Several palaeosol carbonates formed during the Permian (~ 280 Ma), late Triassic (~ 220 Ma) and Jurassic (~200 Ma) are well preserved in the Motur, Denwa and Bagra formations of the Satpura basin, Central India. The  $\delta^{13}\text{C}$  analyses of these carbonates yield  $p\text{CO}_2$  values of 2100, 2300 and 2600 ppmV, about 7-8 times higher than that in the contemporary atmosphere consistent with models of atmospheric  $\text{CO}_2$  evolution.

The first measurements of Re-Os isotopic systematics in black shales from the Himalaya are reported. These measurements pave way for the determination of the chronology of these deposits and their role in contributing to the Os isotope evolution of the oceans since the Cenozoic. The Os isotope ratios,  $^{187}\text{Os}/^{186}\text{Os}$ , are in the range of 8-110, with Os concentrations of 0.04-13 ppb. Model ages for two of the Mussoorie samples, collected from the same horizon are ~ 600 Ma, close to the Rb-Sr ages of ~ 630 Ma for black shales from this region. The

determination of precise chronology of these deposits have implications to the tectonic evolution of the Himalaya.

Evidence for the presence of live  $^{26}\text{Al}$  at the time of formation of a basaltic achondrite has been obtained for the first time from ion microprobe studies of Mg-Al isotopic systematics in plagioclase grains in the Piplia-Kalan eucrite that fell in Rajasthan in 1996. The initial  $^{26}\text{Al}/^{27}\text{Al}$  ratio of  $(7\pm 2)\times 10^{-7}$  suggest a time interval of ~ 5Ma between the formation of the Ca-Al-rich inclusions (CAIs), that are considered to be some of the first solar system solids and the Piplia-Kalan eucrite. Since the basaltic achondrites are product of thermal differentiation, melting and recrystallization taking place in planetesimals representing parent bodies of these meteorites, our result suggests that  $^{26}\text{Al}$  could have played an important role as a heat source in the formation of differentiated meteorites.

The Cretaceous-Tertiary (K/T) boundary sediments show enrichment of Iridium which is attributed to a bolide impact and the contribution due to Deccan volcanism has been considered to be negligible. However, measurement of Ir in some alkali basalts from Anjar K/T section (Kutch, India) show a high iridium concentration, up to 100 pg/g, an order of magnitude higher compared to the tholeiitic basalts. This result indicates higher iridium contribution from Deccan, but this is still inadequate to explain the observed Ir anomaly.

The chemical analysis and dating of carbonatite-alkaline complexes in Deccan show that they were emplaced at a time coincident with the K/T transition. Model calculations show that the carbonatite-alkaline activities could have injected a large amount of  $\text{CO}_2$  and  $\text{SO}_2$  into the atmosphere in a short span of time to significantly enhance the overall stress leading to mass extinction observed at this boundary.

Noble gas studies have revealed that ultramafic xenoliths are very clean samples to look for mantle gases. Simultaneous measurement of noble gas and nitrogen isotopic compositions in ultramafic xenoliths have shown that the mantle has a recycled N component introduced into it through subducted sediments. The pristine degassed mantle had a  $\delta^{15}\text{N} \leq 15\%$  suggesting that the earth was accreted predominantly from enstatite chondrite material.



## Research Facilities

### Major Equipments

Infrared Telescope at Mt. Abu  
Solar Telescopes, Video Magnetograph and Dopplergraph Telescope at Udaipur Solar Observatory  
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  
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

### Computer

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

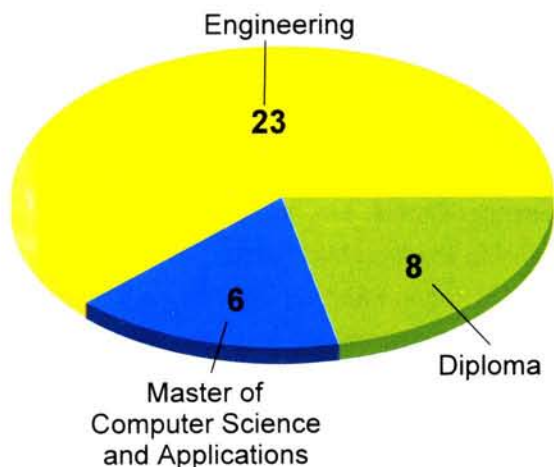
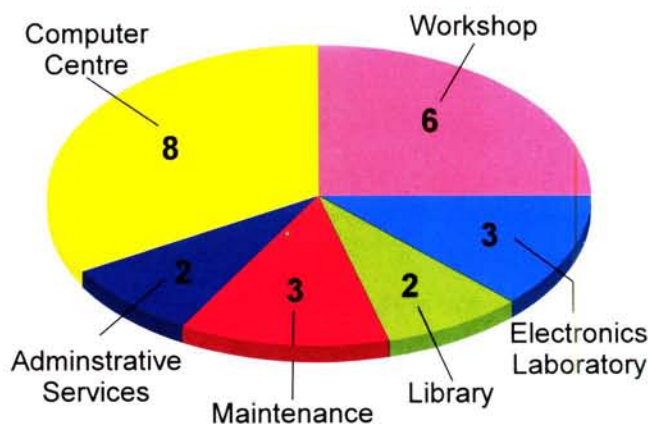
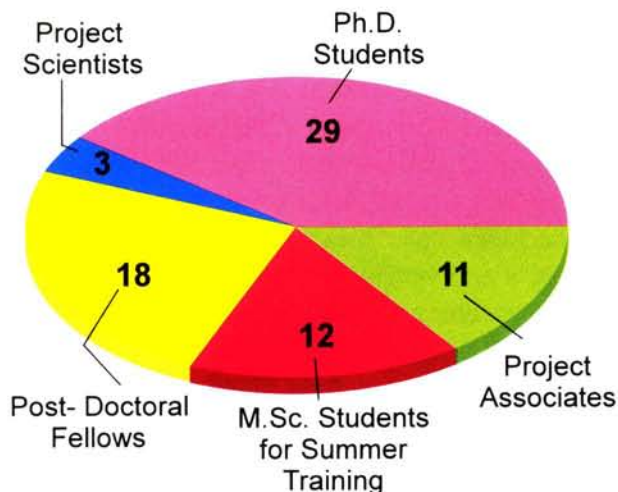
Computer Centre, Electronics Laboratory,  
Scanning Electron Microscope,  
Liquid Nitrogen Plant, Glass Blowing Facility,  
C-14 Dating Laboratory.

### Research Opportunities

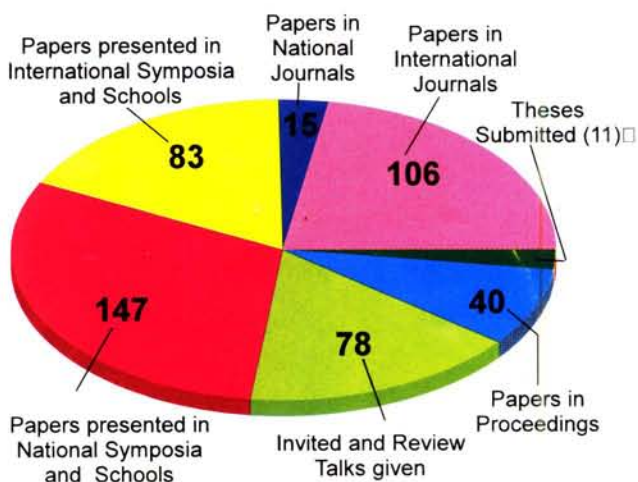
One of the important aims of the laboratory is to serve as a post-graduate and post-doctoral study centre for physics and earth sciences and to train research students in experimental and theoretical physics. With this in view, PRL offers graduate programme leading to Ph. D. degree. It also provides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

### 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.



*Technical Projects for Engineering and Diploma Students*



*Scientific Output of PRL*

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

## 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.

## Books/Journals Edited

D. K. Chakrabarty and S.P. Gupta, *Advances in Space Research*, Vol. 20, No. 11, Pergamon Press, UK, 1997.



## 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. International Conference on Isotopes in the Solar System held at PRL, 11-14 November, 1997 (Convener : Dr. J. N. Goswami).
2. Conference on Nonlinear Dynamics and Computational Physics held at PRL, 18-22 November, 1997 (Convener : Dr. V. B. Sheorey).
3. 10th National Space Science Symposium held at PRL, 25-28 November, 1997 (Convener : Dr. H. Chandra).
4. XVIII Annual Meeting of the Astronomical Society of India held at PRL, November 28 to December 1, 1997 (Conveners : Dr. J.N. Desai, Dr. K. S. Baliyan).
5. National Laser Symposium held at PRL, 10 -12 December, 1997 (Conveners : Dr. J. Banerjee, Dr. Ranjitsingh)
6. Present Trends and Future Directions in Ocean Science held at INSA, New Delhi, October 6-7, 1997 (Convener : Dr. B.L.K. Somayajulu).
7. DST sponsored contact course on "Isotopes in the Solar System", 14-22 July, 1997 (Course Coordinator : Dr. K. Pande).
8. Two-day Workshop on "Pattern Recognition using Neural Network", at Gogte Institute of Technology, Belgaum, 26-27 September, 1997 (Convener : Mr. H. S. Mazumdar).

## Distinguished Visitors at PRL

**Prof. Govind Swarup**, Professor Emeritus, TIFR visited PRL as the twentieth **Vikram A. Sarabhai Professor**. During his visit he gave four lectures and a popular lecture on *Are We Alone in the Universe ?*

**Dr. S. K. Joshi**, Vikram Sarabhai Research Professor, NPL delivered the eleventh **Prof. K.R. Ramanathan Memorial Lecture** entitled *Superconductivity : Fountainhead for New Technologies*.

**Dr. R. Chidambaram**, Chairman, Atomic Energy Commission and Secretary, Dept. of Atomic Energy delivered the twelfth **Prof. K.R. Ramanathan Memorial Lecture** entitled *R & D Challenges in Nuclear Technology*.

As a part of the Golden Jubilee Year Celebrations a number of distinguished visitors were invited. They were Profs. A. Ashtekar, T. D. Swindle, J. V. Narlikar, S. M. R. Ansari, K. D. Abhayankar, D. D. Bhawalkar and Jurgen Ehlers. The visitors had extensive interactions with PRL scientists. They also delivered public lectures.

## Seminars and Colloquia Held

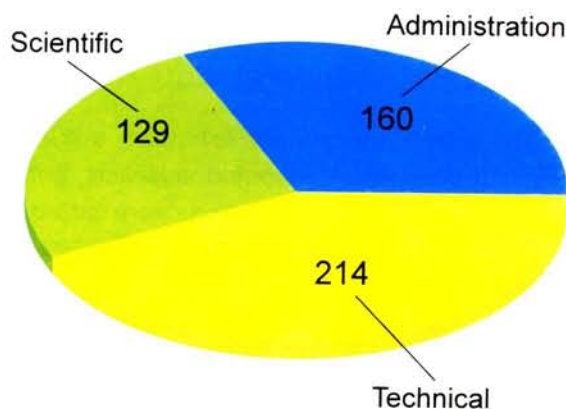
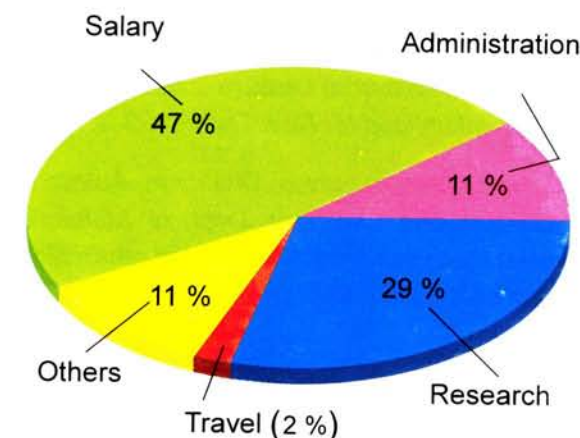
The laboratory has an extensive seminar and colloquium programme. Reputed scientists, both from national and international institutions were invited to give seminars and colloquia. To mark the Golden Jubilee Year celebrations the laboratory organised popular lectures by internationally renowned scientists. The following gives an idea of the seminar and colloquium programmes at PRL :

Seminars held	112
Colloquia including public lectures held	28

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 the staff structure of PRL are as follows:



Staff Structure of PRL

## Miscellaneous

The **National Science Day** was organised on March 1, 1998 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, science exhibition including experiments and exhibits and video shows formed part of the programme. The science quiz was open to students of standards IX to XI from schools all over Gujarat. One hundred and fifty two students participated in the written science quiz. Starting from this year PRL has instituted five 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 and personal interview, held to judge the student's scientific aptitude and motivation for doing science. The five students were Miss K. Shveta from Prakash H. Secondary School; Master Aman Jain from Rachna School; Abhijit Karnik from Little Flower School (all three from Ahmedabad); Saurabh Bhatnagar from Kendriya Vidyalaya, Ankleshwar and Maulik Baxi from Shri Daxinamurthi Vinay Mandir, Bhavnagar. All the five students were awarded Rs. 3000/- per year. The scholarships may be continued for three consecutive years provided the students continue to study in science stream with high academic record.

As a part of implementation and progressive use of Hindi in PRL, the **Hindi Week** was celebrated at PRL from September 15-21, 1997. The highlights of the celebrations included word quiz, essay, elocution, debate, 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 attractions of this years celebration were two scintillating lectures, first was the inaugural lecture delivered by **Prof. Ramlal Parikh**, Chancellor of Gujarat Vidyapeeth and the second was the scientific lecture by the eminent geologist, **Prof. K. S. Valdiya** on *Neotectonic Activities in North Western India*.

To overcome the inhibition to use Hindi in day-to-day official work, a two-day **Hindi Workshop** was held in PRL during February 17-18, 1998 in which about fourteen staff members took part actively. Eight staff members from PRL participated in the DOS Inter Centre Technical Seminar held at MCF, Hassan and papers in various topics were presented. Shri S. K. Shah won the first prize for the best paper. The Hindi Cell also participated in the Rajbhasha Sammelan held in Aurangabad and Hindi Workshops at Space Applications Centre, National Textile Corporation and Aakashvani and delivered lectures on different subjects including Computer Facility Available in the field of Hindi.

## Awards and Honours

1. **Prof. U.R. Rao**, Chairman, PRL Council of Management and Dr. Vikram Sarabhai Distinguished Professor
  - a. has been chosen to take over the *Chairmanship of the United Nations Committee on Peaceful Uses of Outer Space (UN-COPOUS)* for three years beginning from June 1997.
  - b. has been awarded the prestigious *Rathindra Puraskar* by the Visva-Bharati University, Shantiniketan.
  - c. has won the prestigious *Book Award of the International Academy of Astronautics (IAA)* for his book entitled *Space Technology for Sustainable Development*.
  - d. delivered the *Golden Jubilee Lecture on Science and Technology* at Bonn, sponsored by the Federal Ministry of Education, Science Research and Technology, Germany.
2. **Dr. K. Kasturirangan**, Chairman, ISRO and Honorary Fellow of PRL has been awarded
  - a. the *Honorary Fellowship by Indian Meteorological Society*.
  - b. the *MP Birla Memorial Award, 1997* for his outstanding contribution in the field of astronomy, astrophysics and space science.
3. **Prof. G. S. Agarwal**
  - a. has been the recipient of the *Humboldt Research Award (1997)*.
  - b. delivered *K.R. Ramanathan Memorial Lecture* of Indian Geophysical Union, Hyderabad, December, 1997.
  - c. delivered *Platinum Jubilee Lecture* of Indian Science Congress, Hyderabad, January, 1998.
4. **Dr. S. Ramachandran** has been awarded the *1997 Indian National Science Academy (INSA) Medal for Young Scientists* for his outstanding research in the field of Earth Science.
5. **Shri B. L. Panchal** has been chosen for the coveted *Vijay Shree Award alongwith Certificate of Excellence* by the India International Friendship Society.
6. **Prof. R. Sridharan** takes over as the *Regional Editor for the South-east Asian region of the International Journal, J. of Atmospheric and Solar Terrestrial Physics*.
7. The paper entitled *Effect of Space-Weather Related Processes in the Low Latitude-Thermosphere-Ionosphere System* by **R. Sridharan, Alok K. Taori, D. Chakrabarty, R. Narayanan and N. K. Modi** has been adjudged *The Best Paper in Upper Atmosphere at the National Space Science Symposium* held at PRL, Ahmedabad during November 25 -28, 1997.
8. The paper entitled *First Systematic Measurements of Surface O<sub>3</sub>, NO<sub>x</sub>, CO and CH<sub>4</sub> in Urban, Rural, Free Troposphere and Marine Environments over India* by **Manish Naja, Shyam Lal, B. H. Subbaraya, S. Venkataramani and K. S. Modh** has been adjudged *The Best Paper in Middle Atmosphere at the National Space Science Symposium* held at PRL, Ahmedabad during November 25 -28, 1997.
9. The paper entitled *Ancient Martian Atmospheric Signatures from the Antarctic Meteorite ALH84001* by **S.V. S. Murty and R. K. Mohapatra** has been given the *Best Paper Award in Cosmic Rays and Astronomy at the Tenth National Space Science Symposium*, held at PRL, Ahmedabad during November 25 -28, 1997.
10. The paper entitled *Internet - A Powerful Media of Information* by **Shri S. K. Shah** won the *First Prize at the Inter-Centre Technical Seminar of DOS*.



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11. **Pant T. K.**  
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(March 1998)

## Technical Report Submitted during 1997-98

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1. **Jani S., Pandya H. I. and Desai A. H.**  
A Cross Indexed Catalog of Bright Two Micron Sky Survey Sources (PRL-TN-97-78)  
(September 1997)

## INVITED PAPERS

### Astronomy and Astrophysics

1. "Dynamic Activities of the Sun and Solar-Terrestrial Relationship", at the Summer School on Physics & Technology of Materials, Barkatullah University, **Bhopal**, May 1997, by **Ashok Ambastha**.
2. "The Role of Magnetic Shear and New Emerging Fluxes in Triggering Large Flares", at the 18th NSO/SP Workshop on Synoptic Solar Physics, **Sacramento Peak Observatory, USA**, September 9-12, 1997, by **Ashok Ambastha**.
3. "The USO Magnetograph: Instrumentation and Recent Results", at the Joint UAH/NASA Colloquium at Center for Space Plasma and Aeronomic Research, **Huntsville, USA**, September 19, 1997, by **Ashok Ambastha**.
4. Rapporteur talk on "Solar Physics Contributions" at XVIII Meeting of the Astronomical Society of India, PRL, **Ahmedabad**, November 28-December 1, 1997, by **Ashok Ambastha**.
5. "Solar Magnetic Fields at High Resolution and over Large Scales: Physics, Goals, and Observational Requirements", at New Initiatives in Solar Physics Research, Indian Institute of Astrophysics, **Bangalore**, February 20-21, 1998, by **Ashok Ambastha**.
6. "Multiwavelength Observations on Be stars", UPSO Sampurnanand Telescope Silver Jubilee Workshop on "Astronomy with Moderate Size Optical Telescopes", April 1997, **Nainital**, by **B.G. Anandarao**.
7. "Infrared Studies on Circumstellar Matter Around Evolved Stars", XVIII Annual Meeting of Astronomical Society of India, **Ahmedabad**, November-December 1997, by **B.G. Anandarao**.
8. "Planetary Nebulae and the Paleontology of AGB Stars", International Workshop on Stellar Structure and Evolution, February, 1998, **IUCAA, Pune**, by **B.G. Anandarao**.
9. "Near Infrared Occultation Studies of Late Type Stars and Circumstellar Regions from Gurushikhar Observatory", Uttar Pradesh State Observatory Silver Jubilee Workshop, **Nainital**, April 7-9, 1997, by **T. Chandrasekhar**.
10. "Near Infrared Lunar Occultation Observations and Results from Gurushikhar Observatory", Astronomical Society of India, XVIII Meeting, November-December, 1997, at PRL, **Ahmedabad**, by **T. Chandrasekhar**.
11. "High Resolution Polarimetry", New Initiatives in Solar Physics Research, Indian Institute of Astrophysics, **Bangalore**, February 20-21, 1998 by, **Debi Prasad C.**
12. "Giant Pulses from Pulsars", XVIII Annual Meeting of Astronomical Society of India, held at Physical Research Laboratory, **Ahmedabad**, November-December, 1997, by **A.K. Singal**.
13. "Helioseismology and Plasma Physics", at XII National Symposium on Plasma Science & Technology, PRL, **Ahmedabad**, December 2-5, 1997, by **Sushant C. Tripathy**.
14. "Rotation of the Solar Corona and its Signature in Radio Flux", National Solar Physics Workshop at IIA, **Bangalore**, February 20-21, 1998, by **Hari Om Vats**.
15. "Analysis of Galaxy Images obtained with CCD and IR Camera", United Nations/COSPAR/ESA/Brazil Workshop on Data Analysis Technique during 10-14 November 1997, INPE - S.J. Campos, **Brazil**, by **U.C. Joshi**.
16. "Infrared View of the Universe", at XVIII Meeting of Astronomical Society of India during November - December 1997, PRL, **Ahmedabad**, by **U.C. Joshi**.
17. "Star Burst Galaxies: Photometric Study with 1 metre Telescope", UPSO Sampurnanand Telescope Silver Jubilee Workshop on Astronomy with Moderate Size Optical Telescope, April 7-9, 1997, **Nainital**, by **U. C. Joshi**.

## Theoretical Physics

### Gravitation Physics

18. "Ellipticity and Centrifugal Force Behaviour of Slowly Rotating Configurations with Different Equations of State", GR15, International Conference on General Relativity and Gravitation, **Pune**, December 16-21, 1997, by **A. Gupta**.

19. "Geodesic Deviation of Photons in Einstein and Higher Derivative Gravity", GR15, International Conference on General Relativity and Gravitation, **Pune**, December 16-21, 1997, by **S. Mohanty**.
20. "On Basic General Relativity", School on Basic General Relativity and Cosmology, Mangalore University, **Mangalore**, February 9-23, 1998, by **A.R. Prasanna**. (Also Director of the School).

### **High Energy Physics**

21. "*R* Parity Violation: Constraints and Implications", The International Workshop on Physics Beyond Standard Model: from Theory to Experiments. **Valencia, Spain**, October 13-17, 1997, by **A.S. Joshipura**.
22. "Astrophysical Constraints on Particle Properties", in *Whepp-5*, January 11-23, 1998, by **S. Mohanty**.

### **Nonlinear Dynamics and Computational Physics**

23. "Relaxation Fluctuations and Quantum Chaos", Conference on Nonlinear Dynamics and Computational Physics, PRL, **Ahmedabad**, November 18-22, 1997, by **A. Lakshminarayan**.
24. "Estimating Parameters using Synchronization and Adaptive Control", Conference on Nonlinear Dynamics and Computational Physics, PRL, **Ahmedabad**, November 18-22, 1997, by **R.E. Amritkar**.
25. "Regularity in Scarred Wavefunctions of Chaotic Quantum Systems", Conference on Nonlinear Dynamics and Computational Physics, PRL, **Ahmedabad**, November 18-22, 1997, by **V.B. Sheorey**.
26. "Study of Complex Systems through Time Series Analysis: A Dynamic Plus Connectionist Approach", Conference on Nonlinear Dynamics and Computational Physics, **Ahmedabad**, November 18-22, 1997, by **D.R. Kulkarni**.
27. "Characterization, Simulation and Modelling of EEG Time Series", at the International Conference on Non-linear Dynamics and Brain Functioning, **Bangalore**, India, February 5-11, 1998, by **J.C. Parikh**.
28. "Estimation of Parameters using Synchronization and Adaptive Control", at the International Confer-

ence on Nonlinear Dynamics: Integrability and Chaos, Bharathidasan University, **Tiruchirapalli**, February 12-16, 1998, by **R.E. Amritkar**.

29. "Relaxation Fluctuations and Quantum Chaos", International Conference on Nonlinear Dynamics: Integrability and Chaos, at the Bharathidasan University, **Tiruchirapalli**, February 12-16, 1998, by **A. Lakshminarayan**.
30. "Localization in Coupled Quartic Oscillators", International Conference on Nonlinear Dynamics: Integrability and Chaos, held at the Bharathidasan University, **Tiruchirapalli**, February 12-16, 1998, by **M. S. Santhanam**.

### **Nuclear Physics**

31. "Symmetry Schemes for Spectroscopy of Drip Line Nuclei", International Workshop on Physics with Radioactive Nuclear Beams, **Puri**, January 12-17, 1998, by **V. K. B. Kota**.
32. "Embedded and Interpolating Random Matrix Ensembles for Complexity and Chaos in Nuclei", at the V<sup>th</sup> National Workshop on Nuclear Structure Physics, **Chandigarh**, March 17-20, 1998, by **V.K.B. Kota**.

### **Plasma Physics**

33. "Coupled Nonlinear Waves: Integrability and Exact Solutions", International Topical Conference on Plasma Physics - New Perspectives of Collective Effects held at the Abdus Salam International Center for Theoretical Physics, **Trieste**, Italy, November 10-14, 1997, by **N. N. Rao**.
34. "Dusty Plasmas: A Review", Working Group on Dusty Plasmas during Autumn College on Plasma Physics, held at the Abdus Salam International Center for Theoretical Physics, **Trieste**, Italy, October 13 - November 7, 1997, by **N. N. Rao**.
35. "Ionospheric Modification Processes", Working Group on Dusty Plasmas, Autumn College on Plasma Physics, Abdus Salam International Center for Theoretical Physics, **Trieste**, Italy, October 13 - November 7, 1997, by **N. N. Rao**.
36. "Stationary States and Integrable Cases for Coupled Nonlinear Waves", Working Group on Nonlinear



Dynamics and Chaos during Autumn College on Plasma Physics, held at the Abdus Salam International Center for Theoretical Physics, **Trieste**, Italy, October 13-November 7, 1997, by **N. N. Rao**.

## **Laser Physics and Quantum Optics**

37. "Schrödinger Cat States for a Collection of Atoms", Fifth International Conference on Squeezed States, **Hungary**, May 25-30, 1997, by **G.S. Agarwal**.
38. "Schrödinger Cat States for a Collection of Atoms", Symposium-Lamb-Festival, University **Ulm**, July 09-11, 1997, by **G.S. Agarwal**.
39. "Phase Space Distributions and Schrödinger Cat States for a Collection of Atoms", Wigner Symposium, **Vienna**, August 1997, by **G.S. Agarwal**.
40. "Reconstruction of Sub-wavelength Structures", Workshop on Physical Optics and Coherence Theory - Annual Meeting of the Optical Society of America, Long Beach, **California**, USA, October 12-17, 1997, by **G.S. Agarwal**.
41. "Quantum Revival of Wave Packets in Nonlinear Media", National Symposium on Contemporary Physics: Some Aspects, **Calcutta**, November 6-8, 1997, by **G.S. Agarwal**.
42. "Manipulation of Spontaneous Emission", National Laser Symposium, **Ahmedabad**, December 10-12, 1997, by **G.S. Agarwal**.
43. "Quantum Dynamics of Wave Packets and Cat States", International Symposium on Uncertain Reality: The Quantum World-View at Seventy, **New Delhi**, January 5-9, 1998, by **G.S. Agarwal**.
44. Series of **four** lectures on "Control of Optical Properties and Quantum Dynamics of Wave Packets for Nonlinear Systems", Third Frontier Meetings in Physics-Optics: Modern Trends, **Mysore**, January 31-February 05, 1998, by **G.S. Agarwal**.
45. "Evolution Towards Controlled Optical Properties of Matter", Seminar on Lessons from 20th Century Science, **Mumbai**, February 25-26, 1998, by **G.S. Agarwal**.
46. "Cavity QED and Co-operativity in Quantum Jumps in Trapped Ions", Seminar on Physics with Cooled

and Trapped Atoms and Ions, **Mumbai**, March 5-6, 1998, by **G.S. Agarwal**.

47. "Fractional Revivals and Cat-like States", Golden Jubilee Conference on Nonlinear Dynamics and Computational Physics, PRL, **Ahmedabad**, November 18-22, 1997, by **J. Banerji**.
48. "Quantum Dynamics of Wave Packets in Square Well Potential", Symposium on Uncertain Reality, NISTADS, **New Delhi**, January 1998, by **Anu Venugopalan**.
49. "Enhancement of Nonlinear Optical Signals under Coherent Population Trapping Conditions", at National Laser Symposium, **Ahmedabad**, December 10-12, 1997, by **Harshwardhan Wanare**.

## **Planetary Space Sciences and Aeronomy**

50. "Ozone Chemistry in the Tropical Region", Tenth National Space Science Symposium, PRL, **Ahmedabad**, November 25-28, 1997, by **Shyam Lal**.
51. "The Equatorial Ionosphere-Thermosphere System during Geomagnetically Disturbed Periods", International Association of Geomagnetism and Aeronomy (IAGA-97), **Uppsala, Sweden**, during August 4-15, 1997, by **R. Sridharan** and Tarunkumar Pant.
52. "Thermospheric-Ionospheric Interactions", Tenth National Space Science Symposium, PRL, **Ahmedabad**, November 25-28, 1997, by **R. Sridharan**.
53. "Aerosol-Radiation Interaction", Tenth National Space Science Symposium, PRL, **Ahmedabad**, November 25-28, 1997, by **A. Jayaraman**.
54. "Results on Aerosol Radiative Forcing from INDOEX Cruise", National Workshop on Scientific Achievements of ORV Sagar Kanya, National Institute of Oceanography, **Goa**, June 16-17, 1997, by **A. Jayaraman**.
55. "Greenhouse Gases and Climate" and "Aerosols and Climate", IVth SERC School on Dynamics of Climate and its Variability, Indian Institute of Tropical Meteorology, **Pune**, June 18-19, 1997, by **A. Jayaraman**.

56. "Balloonborne Cryogenic Air Sampler for the Study of Atmospheric Trace Gases", at Silver Jubilee Celebrations on Scientific Ballooning in India, TIFR Balloon Facility at **Hyderabad**, January 8-9, 1998, by **Shyam Lal**.
57. "Solar Cycle Effect on Stratospheric Polar Conductivity", Silver Jubilee Celebrations on Scientific Ballooning in India, January 8-9, 1998, **Hyderabad**, by **S.P. Gupta**,

### **Earth Sciences and Solar System Studies**

58. "Astronomical and Terrestrial Causes of Physical, Chemical and Biological Changes at the Geological Boundaries", International Conference on Isotopes in the Solar System, PRL, **Ahmedabad**, November, 11- 14, 1997, by **N.Bhandari**.
59. "Short-lived Nuclides in the Early Solar System", International Conference on Isotopes in the Solar System, PRL, **Ahmedabad**, November, 11- 14, 1997, by **J.N.Goswami**.
60. "Advances in Measurement Techniques: Single Grain Analysis using Ion Microprobe, AMS and Laser Ablation Mass Spectrometry", at the DST sponsored Contact Course on Isotope Geology and Geochemistry, PRL, **Ahmedabad**, July 14-22, 1997, by **J.N.Goswami**.
61. "Methods of Quaternary Geochronology", DST sponsored Contact Course on Isotope Geology and Geochemistry, PRL, **Ahmedabad**, July 14-22, 1997, by **Kanchan Pande**.
62. "Deccan Volcanism", International Conference on Isotopes in the Solar System, PRL, **Ahmedabad**, November, 11- 14, 1997, by **Kanchan Pande**.
63. "Applications of U-Th Series Nuclides in Oceanography and Limnology", DST Sponsored Contact Course on Isotope Geology and Geochemistry, PRL, **Ahmedabad**, July 14-22, 1997, by **S.Krishnaswami**.
64. "Sr Isotopes in the Upper Ganga, Brahmaputra and the Indus Rivers and in Silicates and Carbonates of their Drainage Basins: A Synthesis", International Conference on Isotopes in the Solar System, PRL,

**Ahmedabad**, India, November 11-14, 1997, by **S.Krishnaswami**.

65. "Cosmic Rays and Cosmic-ray Produced Nuclides", DST sponsored Contact Course on Isotope Geology and Geochemistry, PRL, **Ahmedabad**, July 14-22, 1997, by **S.V.S.Murty**.
66. "Noble Gas Systematics and Geochemical Applications", DST Sponsored Contact Course on Isotope Geology and Geochemistry, PRL, **Ahmedabad**, July 14-22, 1997, by **S.V.S.Murty**.
67. "Proxy Sources and Dating Methods, Palaeoclimatic Response and Transfer Functions", **three** Lectures at the IV SERC School on Advanced Geophysical Fluid Dynamics, Indian Institute of Tropical Meteorology, **Pune**, June 12-13, 1997, by **R. Ramesh**.
68. "Stable Isotopes and Applications in Earth Sciences", Course of Lectures at the DST Sponsored Orientation Course for University Teachers, PRL, **Ahmedabad**, July 14-28, 1997, by **R. Ramesh**.
69. "Late Quaternary Climatic Changes in Tropical South India: Oxygen and Carbon Isotopic Evidence from Peat Bogs", International Conference on Isotopes in the Solar System, PRL, **Ahmedabad**, November 11-14, 1997, by **R. Ramesh**.
70. "Palaeomonsoon: Data and Models", Indian Academy of Sciences Meeting on Monsoons: Past, Present and Future, **Coorg**, November 20-22, 1997, by **R. Ramesh**.
71. "Particle Scavenging Processes in the Bay of Bengal: Inferences from  $^{238}\text{U}$  Decay Series Nuclides", International Conference on Isotopes in the Solar System, PRL, **Ahmedabad**, November 11-14, 1997, by **M.M. Sarin**.
72. "Holocene Palaeoenvironmental Changes in the Lower Mahi Basin, Western India", Sixteenth International  $^{14}\text{C}$  Conference, Groningen, **The Netherlands**, June 16-20, 1997, by **Sheela Kusumgar**.
73. "A 3400 Year Environmental Record Based on Stable Isotope Study of a Speleothem from Gupteswar, Orissa", Tenth National Space Science Symposium, PRL, **Ahmedabad**, November 25-28, 1997, by **M. G. Yadava**

## Astronomy and Astrophysics

74. "Fabry-Perot Filter Based Solar Video Magnetograph", XVIII ASI Annual Meeting, Ahmedabad, 1997, by Shibu K. Mathew, Debi Prasad C., Ashok Ambastha and Arvind Bhatnagar.
75. "Velocity and Magnetic Field in the Super Active Region NOAA 6555 and 6659", 10 th National Space Science Symposium, 1997, Ahmedabad, by Debi Prasad C., Nirav Mehta, Ashok Ambastha and Shibu K. Mathew.
76. "The Solar Activity in NOAA Active Region No.8038 during 10 - 13 May, 1997", 31st ESLAB Symposium on Correlated Phenomena at the Sun, in the Heliosphere and in Geospace, ESTEC, Noordwijk, **The Netherlands**, 22-25 September, 1997, by Rajmal Jain.
77. "The H-alpha Flare of 12 May, 1997 and Associated Phenomena", National Space Science Symposium (NSSS), PRL, Ahmedabad, 25 - 28 November, 1997, by Rajmal Jain.
78. "H-alpha and Hard X-ray Activity Near West Limb of the Sun on April 13, 1980", National Space Science Symposium (NSSS), PRL, Ahmedabad, 25 - 28 November, 1997, by Rajmal Jain.
79. "Chromosphere as an Acceleration Site for Electrons/ Protons Causing Hard X-ray Solar Flares", Annual Meeting of Astronomical Society of India, PRL, Ahmedabad, November - December, 1997, by Rajmal Jain.
80. "Solar Variability in the Middle Ultraviolet Region During the Descending Phase of Solar Cycle 22", National Solar Physics Meeting, IIA, Bangalore, 20-21 February, 1998, by Rajmal Jain.
81. "Helioseismic Determination of Opacity using GONG Frequencies", XVIII ASI Meeting, PRL, Ahmedabad, November - December, 1997, by S.C. Tripathy.
82. "Sensitivity of the Solar Neutrino Flux to Opacity Changes", at XVIII ASI Meeting, PRL, Ahmedabad, November 28-December 1, 1997, by S.C. Tripathy and K. Jain.
83. "Interferometric Spectroscopy of Cometary Plasma", UPSO Sampurnanand Telescope Silver Jubilee Workshop on Astronomy with Moderate Size Optical Telescopes, April 1997, Nainital, by J.N. Desai, B.G. Anandarao, T. Chandrasekhar, S.D. Rawat and D.B. Vaidya.
84. "Possible Trends in Expansion Velocities of Planetary Nebulae Evolved from Common Envelope Binary Systems", XVIII Annual Meeting ASI, November-December, 1997, PRL, Ahmedabad, by C. Muthu and B.G. Anandarao.
85. "A Kinematic Study of the Planetary Nebula NGC 246 in the [OIII] 5007 A line", XVIII Annual Meeting of ASI, November-December, 1997, PRL, Ahmedabad, by C.Muthu and B.G. Anandarao.
86. "Interstellar Grains Towards Orion", XVIII Annual Meeting of ASI, November-December 1997, PRL, Ahmedabad, by D.B. Vaidya, B.G. Anandarao and J.N. Desai.
87. "On the Accuracy of Caustic Test", XVIII Annual Meeting of ASI, November - December, 1997, PRL, Ahmedabad, by D.P.K. Banerjee, R.V. Willstrop and B.G. Anandarao.
88. "A Near-Infrared Imaging Fabry-Perot Spectrometer", XVIII Annual Meeting of ASI, November-December, 1997, PRL, Ahmedabad, by M.S. Nandakumar and B.G. Anandarao.
89. "A Two Channel High Speed Photometer for Lunar Occultation Studies in the Near Infrared", XVIII Annual Meeting of ASI, November-December, 1997, PRL, Ahmedabad, by Soumen Mondal, T. Chandrasekhar, N.M. Ashok and P.K. Kikani.
90. "Study of Variability in the Angular Size of Suspected Mira Variable IRC-20563 from Lunar Occultation Observations at 2.2 Microns", XVIII Annual Meeting of the Astronomical Society of India, PRL, Ahmedabad, November-December 1997, by Anandamayee Tej, T. Chandrasekhar and N.M. Ashok.
91. "Recent Period Variations of the Algol Binary System RZ Cas", XVIII Annual Meeting of ASI, November-December, 1997, PRL, Ahmedabad, by Watson P.V., N.M. Ashok and T. Chandrasekhar.



92. "Near Infrared Photometry and Apparent Period Variations of Eclipsing Binary System RCMa", XVIII Annual Meeting of ASI, November-December, 1997, PRL, Ahmedabad, by Watson P.V., N.M.Ashok and T. Chandrasekhar.
93. "Correlation and Fractal Analysis of Solar Radio Emission", UN/ESA/COSPAR Workshop at INPE, **Brazil**, November 10-14, 1997, by Hari Om Vats, M.R. Deshpande, M. Mehta, C.R. Shah and K.J. Shah
94. "The H-alpha Flare of 12 May 1997 and Associated Phenomena", Presented at National Space Science Symposium at Physical Research Laboratory, Ahmedabad, November 25-28, 1997, by Rajmal Jain, Nirav Mehta, Hari Om Vats, M.R. Deshpande, Shibu K. Mathew, H. Chandra, Vladimir Bogod, S. Nagai, Som Sharma, E. Sagawa, Susan Tokhchukova, K.N. Iyer, Rupal Oza and Saroj Rathore.
95. "Parameters of Interplanetary Medium Using Diffractive - Refractive Scattering Approach and IPS Observations", Presented at National Space Science Symposium at Physical Research Laboratory, Ahmedabad, November 25-28, 1997, by Rupal M. Oza, Hari Om Vats, K.N. Iyer and M.R. Deshpande.
96. "Radio Emission as a Diagnostics for Solar Coronal Rotation", Astronomical Society of India Meeting held at Physical Research Laboratory, November-December 1997, by Hari Om Vats, M.R. Deshpande, M. Mehta, C.R. Shah and K.J. Shah.
97. "A Possible Detection of Radio Pulses from Geminga" Astronomical Society of India Meeting held at Physical Research Laboratory, November - December 1997, by Hari Om Vats, Ashok K. Singal, M.R. Deshpande, Chhaya R. Shah and S. Doshi.
98. "Enhanced Giant Pulsation Activity of Pulsar 0950+08", Astronomical Society of India Meeting held at Physical Research Laboratory, November-December 1997, by Ashok K. Singal, Hari Om Vats, M.R. Deshpande, Chhaya R. Shah and S. Doshi
99. "Convective Flows of Solar Plasma", 12th National Symposium on Plasma Science and Technology, held at PRL, December 2-5, 1997, by Hari Om Vats, C.R. Shah, S. Tripathy, A. Ambastha and M.R. Deshpande.
100. "Measurements of Solar Wind Velocities Close to the Sun Using Ulysses Radio Sounding Data", XXII General Assembly of the European Geophysical Society, **Vienna**, April 21-25, 1997, by P. Janardhan, M.K. Bird, P. Edenhofer, D. Plettemeier, R. Wohlmuth, S.W. Asmar, M. Patzelt and J. Karl.
101. "Coronal Velocity Measurements with Ulysses : Multi-link Correlation Studies During two Superior Conjunctions", 8th Scientific Assembly of IAGA, Uppsala, **Sweden**, August 4-15, 1997, by P. Janardhan, M.K. Bird, P. Edenhofer, D. Plettemeier, R. Wohlmuth, S.W. Asmar, M. Patzelt and J. Karl.
102. "Tracking Interplanetary Disturbances Using Inter Planetary Scintillation", 31 st ESLAB Symposium on Correlated Phenomenon at the Sun in the Heliosphere and in Geospace, Noordwijk, **The Netherlands**, September 22-25, 1997, by P. Janardhan, V. Balasubramanian and S. Ananthakrishnan.
103. "K-band Radio Observations of Comet Hale-Bopp : Detections of Ammonia and (possibly) Water", First International Conference on Hale-Bopp, Puerto de la Cruz, Tenerife, **Spain**, February 2-6, 1998, by M.K. Bird, P. Janardhan, T.L. Wilson, W.K. Huchtmeier, P. Gensheimer, and C. Lemme.
104. "On the Accuracy of the Caustic Test", XVIII th ASI Meeting, PRL, November - December 1998, by D.P.K. Banerjee, R.V. Willstrop and B.G. Anandarao.
105. "A Polarization Study of the Comet Hale-Bopp: Grain Properties", XVIII ASI Meeting, PRL, November - December, 1997, by K.S. Baliyan, S. Ganesh, K.J. Shah, U.C. Joshi and M.R. Deshpande.
106. "Mg V Collisional Excitation Data of Interest in Solar Study", XVIII ASI Meeting, PRL, November - December, 1997, by K.S. Baliyan and U.C. Joshi.
107. "Imaging Polarimetry of Comet Hale-Bopp", XVIII ASI Meeting, PRL, November - December, 1997, by S. Ganesh, U.C. Joshi, A. Chitre, K.S. Baliyan and M.R. Deshpande.
108. "Wide Field Imaging Polarimetry of Comet Hale-Bopp", XVIII ASI Meeting, PRL, November - December, 1997, by S. Ganesh, U.C. Joshi, M. R.

Deshpande, N.M. Vadher, A.B. Shah and S.N. Mathur

109. "Polarimetric Study of Sakurai's Object", XVIII ASI Meeting, PRL, November- December, 1997, by S. Ganesh, U.C. Joshi, M.R. Deshpande and N. Kameswara Rao.
110. "Photometric Studies of Starburst Galaxies", XVIII ASI Meeting, PRL, November-December, 1997, by Aparna Chitre and U.C. Joshi
111. "Time Variability of Polarization in BL Lac Objects : OJ287, Mrk421, Mrk501", XVIII ASI Meeting, PRL, November - December, 1997, by U.C. Joshi, Shashikiran Ganesh and M.R. Deshpande.
112. "PRL Near Infrared Camera - Detector Noise Characteristics", XVIII ASI Meeting, PRL, November-December, 1997, by U.C. Joshi, Shashikiran Ganesh, A.B. Shah, N.M. Vadher, K.S.B. Manian and M.R. Deshpande.
113. "Near Infrared Polarimeter", XVIII ASI Meeting, PRL, November-December, 1997, by K.S.B. Manian, Vishal Shah, Mary Thomas, U.C. Joshi and S. Ganesh.
114. "JHK Photometry of V4334 Sgr - Sakurai's Peculiar Variable", XVIII ASI Meeting PRL, November-December, 1997, Ahmedabad, by U.S. Kamath and Ashok N.M.
115. "Near IR Photometry and Apparent Period Variations of the Eclipsing Binary System R CMa", XVIII ASI Meeting, PRL, November-December, 1997, Ahmedabad, by P.V. Watson, N.M. Ashok and T. Chandrasekhar.
116. "Recent Period Variations of the Algol Binary System RZ Cas", XVIII ASI Meeting, PRL, November-December, 1997, Ahmedabad, by P.V. Watson, N.M. Ashok and T. Chandrasekhar.
117. "Study of the Intrinsic Variability in the Angular Size of the Suspected Mira Variable IRC-20563 from Lunar Occultation Observations at 2.2 micron", XVIII ASI Meeting, PRL, November-December, 1997, Ahmedabad, by A. Tej, T. Chandrasekhar and N.M. Ashok.
118. "A Two Channel High-Speed Photometer for Lunar

Occultation Studies in the Near-Infrared", XVIII ASI Meeting, PRL, November-December, 1997, Ahmedabad, by S. Mondal, T. Chandrasekhar, N.M. Ashok and P.K. Kikani.

119. "A PC Based Telescope Control Computer (TCC) for the Gurushikhar IR Observatory", XVIII ASI Meeting, PRL, November-December, 1997, Ahmedabad, by R.R. Shah, H.T. Rangooni, A.B. Shah, N.S. Jog and D.V. Subhedar.

## **Theoretical Physics**

### **Atomic and Molecular Physics**

120. "A BBK-type Theory for Angular Correlation Parameters for Electron Impact Excitation of H(2p)", Twentieth International Conference on The Physics of Electronic and Atomic Collisions, Vienna, **Austria**, 23-29 July, 1997, by D.P. Dewangan.

### **Non Linear Dynamics and Computational Physics**

121. "Sensitivity of PRL-GCM to Sea Surface Temperature Anomalies", National Space Science Symposium held at PRL, Ahmedabad, November 25-28, 1997, by S. V. Kasture, Biju Thomas and V. Satyan.

## **Laser Physics and Quantum Optics**

122. "Generic Nonlinearities and Cat-Like States", Symposium on Quantum Optics for Communications, Annual Meeting of the Optical Society of America, , Long Beach, **California**, USA, October 12-17, 1997, by G.S. Agarwal and J. Banerji.
123. "Optical Manipulation of Patterns", Joint Symposium on Coherent Control, Annual Meeting of the Optical Society of America, , Long Beach, **California**, USA, October 12-17, 1997, by G.S. Agarwal and J. Banerji.
124. "Statistical Generalization of the Optical Cross-Section Theorem and a New Reconstruction Technique", Annual Meeting of the Optical Society of America, , Long Beach, **California**, USA, October 12-17, 1997, by G.S. Agarwal, P. Scott Carney and E. Wolf.
125. "Quantum Noise Limits on Spatial Soliton Propagation", CLEO/QELS 1997, **Baltimore**, May 18-23, 1997, by E.M. Nagasako, R.W. Boyd and G.S. Agarwal.

126. "Fractional Revival, and Cat-Like States in Systems with More than One Time Scale", National Laser Symposium, Ahmedabad, December 10-12, 1997, by J. Banerji and G. S. Agarwal.
127. "Sign Reversal of Bistable Loop in Injection Locked Diode Laser", National Laser Symposium, Ahmedabad, December 10-12, 1997, by S. Sivaprakasam and Ranjit Singh.
128. "Laser Field Induced Quantum Beats in Two Photon Correlations", National Laser Symposium, Ahmedabad, December 10-12, 1997, by Anil K. Patnaik.
129. "Schrödinger Cat States and Decoherence", National Laser Symposium, Ahmedabad, December 10-12, 1997, by Anu Venugopalan.
130. "Effects of Spontaneously Generated Coherence on Pump-probe Response of a System", National Laser Symposium, Ahmedabad, December 10-12, 1997, by Sunish Menon.
131. "Squeezing in Downconversion in Quasi-Phase Matched Medium", National Laser Symposium, Ahmedabad, December 10-12, 1997, by V. S. Chickarmane.
132. "Quantum Coherence : Source of Beat in Photon Correlations", Seminar on Physics with Cooled and Trapped Atoms and Ions, Bombay, March 5-6, 1998, by Anil K. Patnaik.
133. "Is Coherent Population Trapping Preserved in the Presence of Inherent Interference Effects ?", Seminar on Physics with Cooled and Trapped Atoms and Ions, Bombay, March 5-6, 1998, by Sunish Menon.
- Manish Naja, Shyam Lal, B.H. Subbaraya, S. Venkataramani, and K.S. Modh.
136. "Variabilities in the Fluxes and Annual Budget of Greenhouse Gases from the Arabian Sea", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by Prabir K. Patra, S. Venkataramani and Shyam Lal.
137. "Large Variabilities in Ozone and Precursor Gases over the Indian Ocean", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by Shyam Lal, Manish Naja, K.S. Modh and S. Venkataramani.
138. "An Experimental Study on the Dependence of Spectral Aerosol Optical Depth on Aerosol Size Distribution", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by A. Jayaraman, Y.B. Acharya and B.H. Subbaraya.
139. "Marine Aerosol Optical Depths from MOS-B Data", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by A.K. Mathur, R.M. Dwivedi, H.U. Solanki, M. Mohan and Y.B. Acharya.
140. "Rayleigh Lidar at Mt. Abu - First Results", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by H. Chandra, A. Jayaraman, Y. B. Acharya and S. Sharma.
141. "Long-term Trend of Total Ozone over Ahmedabad", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by D.K. Chakrabarty, N.C. Shah, and K.V. Pandya.
142. "Role of Sprites in Stratosphere and Mesosphere", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by S.P. Gupta,
143. "A New Approach to Parameterise the Local and Nonlocal Processes into the MSISE-90 Model and its Application to Low Latitudes", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997; by Tarunkumar Pant and R. Sridharan.
144. "Daytime Mesopause OH Rotational Temperatures from Equatorial Latitudes - First Results", 10th National Space Science Symposium, PRL,

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134. "Sulphur Hexafluoride ( $\text{SF}_6$ ) - An Ideal Tracer for Atmospheric Transport", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by Shyam Lal and Prabir K. Patra.
135. "First Systematic Measurements of Surface  $\text{O}_3$ ,  $\text{NO}_2$ ,  $\text{CO}_2$  and  $\text{CH}_4$  in Urban, Rural, Free Troposphere and Marine Environment over the Indian Region", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by



Ahmedabad, November 25-28, 1997, by R. Sridharan, Alok K. Taori, N.K. Modi, R. Narayanan, D. Chakrabarty and M.G. Shepherd.

Dayside Ionosphere of Mars", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by K.S. Raina and S.A. Haider.

145. "Imprint of the Equatorial Electrodynamical Processes in OI 630.0 nm Dayglow", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by R. Sridharan, V.V. Somayajulu, D.Pallam Raju, Alok K. Taori, D.Chakrabarty, and R. Raghavarao.
146. "Effect of Space-Weather Related Processes in the Low Latitude Thermosphere-Ionosphere System" 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by R. Sridharan, Alok K. Taori, D. Chakrabarty, R. Narayanan and N.K. Modi.
147. "Ground-based Optical Observations of Daytime Aurora from Maitri - A Potential Means of Space-Weather Investigations", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by D. Pallam Raju and R. Sridharan.
148. "HF Doppler Measurements over Ahmedabad", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by S. R. Das, K.V. Pandya, H. Chandra and R. Raghavarao.
149. "Short Time-Scale Features of MST Radar Returns", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by D. A. Hooper, H. Chandra and S. Sharma.
150. "In-situ Measurements of Electron Density and Electric Field during Equatorial Spread F" at the 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by Shikha Raizada, H.S.S.Sinha and R.N.Misra.
151. "Long Term Changes of Ionosphere Over Ahmedabad", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by Som Sharma, H. Chandra and G. D. Vyas.
152. "Calculation of Ion Densities for Masses 12-40 Amu in the Inner Coma of Comet Halley", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by S.A. Haider and A. Bhardwaj.
153. "Solar Cycle Variation of Electron Densities in the
154. "Nightglow Limb Intensities of 5577 Å and 6300 Å in the Martian ionosphere", 10th National Space Science Symposium, PRL, Ahmedabad, November 25-28, 1997, by S.A. Haider.
155. "Some Results on Turbulence Parameters from Tirupati MST Radar", International MST Radar Workshop 8, **Bangalore**, December-15-20, 1997, by D.K. Chakrabarty and S.R. Das.
156. "Rocketborne Investigation of E-region Irregularities Comparison with MST Radar Measurements", Eighth International Workshop on Scientific and Technical aspects of MST Radar, December 15-20, 1997, **Bangalore**, by S.P. Gupta.
157. "The Evolution and Structure of Layers of Clear Air Turbulence: A Review of S-Band Radar Observations", 8th International Workshop on Technical and Scientific Aspects of MST Radar, **Bangalore**, India, December 15-20, 1997, by D. A. Hooper.
158. "Layers of Intense Turbulence in the Troposphere and Lower Stratosphere Identified From Combined MST Radar and Radiosonde Observations at Aberystwyth", 8th International Workshop on Technical and Scientific Aspects of MST Radar, **Bangalore**, India, December 15-20, 1997, by Hooper, D. A., and L. Thomas.
159. "Discrepancies Between Frequency and Time Domain Corrected MST Radar Signals", 8th International Workshop on Technical and Scientific Aspects of MST Radar, **Bangalore**, India, December 15-20, 1997, by D. A. Hooper.
160. "Simultaneous Measurement of Vertical Electric Field and Electron Density Fluctuations during Spread F over SHAR", Plasma-97, December 2-5, 1997, PRL, Ahmedabad, by Shikha Raizada, H.S.S.Sinha and R.N.Misra,
161. "Aerosol Radiative Forcing Studied from CR109 and CR120 Data", INDOEX International Workshop, at the Scripps Institute of Oceanography, La Jolla, **San Diego**, USA, during September 8-12, 1997, by A. Jayaraman.

162. "Evidence for Significant Upper Thermospheric Contribution to OI S 557.7 nm Dayglow, by Ground Based Dayglow Photometry", (IAGA-97), Uppsala, **Sweden**, August 4-15, 1997, by R. Sridharan, Alok K. Taori, Tarun K. Pant, D. Chakrabarty, and D. Pallam Raju.
163. "Ground Based Optical Observations of Daytime Auroral Emissions - a Potential Means of the Investigation of Space-Weather Related Processes", (IAGA-97), Uppsala, **Sweden**, August 4-15, 1997, by D. Pallam Raju and R. Sridharan.
164. "Imprint of the Equatorial Electrodynamical Processes in the OI 630.0 nm Dayglow", (IAGA-97), Uppsala, **Sweden**, August 4-15, 1997, by R. Sridharan, D. Pallam Raju and R. Raghavarao.
165. DEOS : "Dynamics of the Equatorial Ionosphere over SHAR - Indo-German Low Latitude Project", European Space Agency Symposium, **The Netherlands** 1977, by H. Thiemann, G. Mayer, A. Piel, C. Stages, N. Olsen, F. Primdahl, R. Sridharan, S.P. Gupta, G.K. Rangarajan, D.R.K. Rao and P.B. Rao.
166. "Distributions of O<sub>3</sub> and CO<sub>2</sub> over the Tropical Indian Ocean", International Symposium on Atmospheric Chemistry and Future Global Environment, Nagoya, **Japan**, November 11-13, 1997", by Shyam Lal and Manish Naja.
167. "Measurements of Surface Ozone and Precursors in Urban, Rural and Free Tropospheric Sites over the Tropical India", International Symposium on Atmospheric Chemistry and Future Global Environment, Nagoya, **Japan**, November 11-13, 1997, by Manish Naja, Shyam Lal, S. Venkataramani and B.H. Subbaraya.

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168. "Deciphering Monsoonal/Climatic Changes During the Past Millennium Using Continental Margin Sediments off the West Coast of India", International Conference on Isotopes in the Solar System, **Ahmedabad**, India, November 11-14, 1997, by R. Agnihotri, R. Bhushan, K. Dutta, Ashish Sarkar and B.L.K. Somayajulu.
169. "<sup>147</sup>Sm-<sup>143</sup>Nd Age of Piplia Kalan Eucrite", Interna-

tional Conference on Isotopes in the Solar System, **Ahmedabad**, November 11-14, 1997, by Anil Kumar, K. Gopalan and N. Bhandari.

170. "Isotopic Composition of Sulphur in Gypsum-Anhydrite Layers and Carbon Oxygen in Interlayered Dolomites in Borehole Samples of the Hanseran Formation (Nagpur Basin)" in International Conference on Isotopes in the Solar System, **Ahmedabad**, India, November 11-14, 1997, by D.M. Banerjee, H. Strauss, S.K. Bhattacharya, A. Mazumdar and V. Kumar.
171. "Progressive Changes in Carbon Isotopic Composition of Mesoproterozoic Sea : Evidence from Semri Group, Son Valley, India", in International conference on Isotopes in the Solar System, **Ahmedabad**, India, November 11-14, 1997, by S. Banerjee, S. Sarkar, S.K. Bhattacharya and R.A. Jani.
172. "Correlated Double Iridium and  $\delta^{18}\text{O}$  Peaks Across Koshak K/T boundary and their Environmental Implications", International Conference on Isotopes in the Solar System, **Ahmedabad**, November 11-14, 1997, by N. Bhandari, P.N. Shukla and S.K. Bhattacharya.
173. "The Ages and Orbit of Piplia Kalan Eucrite", International Conference on Isotopes in the Solar System, **Ahmedabad**, November 11-14, 1997, by N. Bhandari, S.V.S. Murty, K.M. Suthar, A.D. Shukla, G.M. Ballabh, R. Natarajan, M.S. Sisodia and K.V. Vaya.
174. "Enigmatic Deposits from Peninsular Gondwana of Eastern India: Freshwater Stromatolites or Travertines", in International Conference on Isotopes in the Solar System, **Ahmedabad**, India, November 11-14, 1997, by S.K. Bhattacharya, P. Ghosh, A. Chakrabarti and K.L. Pandya.
175. "An Explanation of the Anomalous Isotopic Composition in Stratospheric Carbondioxide", Tenth National Space Science Symposium, **Ahmedabad**, India, November 25-28, 1997, by S.K. Bhattacharya, R.J. Francey, C.E. Allison, U. Schmidt and T. Gamo.
176. "Natural and Bomb Radiocarbon in the Arabian Sea and Overhead Air: Time Scale Estimates of Air Sea Exchange and Water Mixing", International Conference on Isotopes in the Solar System, **Ahmedabad**,

- India, November 11-14, 1997, by R. Bhushan, B.L.K. Somayajulu and S. Krishnaswami.
177. "Radiocarbon in the Arabian Sea and Overhead Atmosphere", XVth International Radiocarbon Conference, Gröningen, **Netherlands**, June 16-20, 1997, by R. Bhushan, B.L.K. Somayajulu, S. Chakraborti and S. Krishnaswami.
  178. "Century Scale Heliospheric Modulation of Galactic Cosmic rays by  $^{44}\text{Ti}$  Measurements in Meteorites", International Conference on Isotopes in the Solar System, **Ahmedabad**, November 11-14, 1997, by G.Bonino, N.Bhandari, G.Cini Castagnoli, P.Della Monica and C.Taricco.
  179. "Decadal and Century Scale Modulation of Cosmogenic Radionuclides Measured in Meteorites", Annual Meeting of the Meteoritical Society, **Hawaii**, July 21-25, 1997, by G.Bonino, G.C.Castagnoli, C.Taricco, P.Della Monica and N.Bhandari.
  180. "Tandem Measurements of TSL and IRSL on Feldspar Extracts from Thar Desert Sand Dune Samples", Proc. National Symposium on Luminescence and Applications', Raipur, October 14-16, 1997, by M.P. Chougankar, A.K. Singhvi and K.S.V. Nambi.
  181. "Marine Radionuclide Studies : A Silver Jubilee of PRL - University of Delaware Collaboration", International Conference on Isotopes in the Solar Systems, **Ahmedabad**, India, November 11-14, 1997, by T.M. Church, B.L.K. Somayajulu, M.M. Sarin, P. Sharma, N. Hussain and R. Rengarajan.
  182. "Oxygen Isotopic Composition of Surface and Ground Water along West Coast Region of India", International Conference on Isotopes in the Solar System : **Ahmedabad**, India, November 11-14, 1997, by R.D. Deshpande, S.K. Bhattacharya, S.K. Gupta and R.A. Jani.
  183. " $^{13}\text{C}/^{12}\text{C}$  Studies on the Assessment of Water-use Efficiency of Vegetation in an Agroecosystem", International Conference on Isotopes in the Solar System, **Ahmedabad**, India, November 11-14, 1997, by P.S. Dutta, S.K. Bhattacharya, S.K. Tyagi and R.A. Jani.
  184. "Decline of Atmospheric  $\text{CO}_2$  Level: Evidence from Indian Phanerozoic Palaeosols", International Conference on Isotopes in the the Solar System: **Ahmedabad**, India, November 11-14, 1997, by P. Ghosh, S.K. Bhattacharya, S. Roy and R.A. Jani.
  185. "Anomaly of Atmospheric  $\text{CO}_2$  Level : Evidence from the Indian Gondwana Palaeosol", VIIIth ISMAS Workshop on Mass Spectrometry, Mumbai, August 4-9, 1997, India, by P. Ghosh and S.K. Bhattacharya.
  186. "Palaeohydrology of Gondwana Basins Based on Strontium Isotopic Ratios in Carbonates from Talchir Deposits of Peninsular India", International Conference on Isotopes in the Solar System, **Ahmedabad**, November 11-14, 1997, by P.Ghosh, J.R.Trivedi, S.K.Bhattacharya, A.M. Dayal, K. Gopalan and A. Chakrabarti.
  187. "A Sustainable Water Resources Development Plan for Ahmedabad: 2001 and Beyond - An Outline Proposal", ACT-WRRF-AMC Workshop, Ahmedabad, April 5, 1997, by S.K. Gupta and P. Nema.
  188. "Geohydrology in Relation to Water Management in India: Research Needs ", Workshop on Water Pollution - Assessment and Management, NGRI, Hyderabad, October 9-10, 1997, by S.K. Gupta.
  189. "Modelling Contamination of Drinking Water Supply Well in Sabarmati Riverbed, Ahmedabad City", National Symposium on Sustainable Groundwater Development and Management, Anna University, Chennai, November 5-8, 1997, by V.V.S. Gurunada Rao and S.K. Gupta.
  190. "Geochemistry of U and Th in the Anoxic Deep Waters of the South Eastern Arabian Sea", International Conference on Isotopes in the Solar System, PRL, **Ahmedabad**, India, November 11-14, 1997, by N. Hussain, M.M. Sarin and T.M. Church.
  191. "Palaeoclimatological Studies on South Asian Monsoon Using CCM2 GCM", International Symposium on Asian Monsoon and Pollution over the Monsoon Environment, IIT, **Delhi**, December 2-5, 1997, by Jagadheesha, R., Nanjundiah and R. Ramesh
  192. "A Post Rajmahal Trap Alkali Magmatism at Sung Valley, North-Eastern India : Evidence from  $^{40}\text{Ar}$ - $^{39}\text{Ar}$  Chronology", International Conference on Isotopes in the Solar System, **Ahmedabad**, November



- 11-14, 1997, by Jyotirnanjan S. Ray and Kanchan Pande.
193. "Reactivation of Pre-Existing Faults During Basin Inversion : Evidence from  $^{40}\text{Ar}$ - $^{39}\text{Ar}$  Chronology of Himalayan Mafic Volcanics", International Conference on Isotopes in the Solar System, **Ahmedabad**, November 11-14, 1997, by Kanchan Pande and M.I. Bhat.
  194. "Precise Determination of  $^{196}\text{Hg}/^{202}\text{Hg}$  Ratio in Meteorites and Terrestrial Standard Rocks by Radiochemical Neutron Activation", International Conference on Isotopes in The Solar System: **Ahmedabad**, India, November 11-14, 1997, by P. Kumar, M. Ebihara, H. Nakahara and S.K. Bhattacharya.
  195. "Boron Isotope Composition in Anorthites from an Efremovka Calcium-Aluminium-rich Inclusion", Annual Meeting of Meteoritical Society, **Hawaii**, July 21-25, 1997, by K.K.Marhas and J.N.Goswami.
  196. "Depth Profiles of Long-lived Cosmogenic Radionuclides in Mbale", Annual Meeting of the Meteoritical Society, **Hawaii**, July 21-25, 1997, by S.Merchel, U.Herpers, S.Neumann, R.Michel, P.W.Kubic, M.Suter, D.Faestermann, K.Knie, G.Korschinek, T.Satz and N.Bhandari.
  197. "Search for Mantle Nitrogen in the Ultramafic Xenoliths from San Carlos, Arizona", International Conference on Isotopes in the Solar System, **Ahmedabad**, November 11-14, 1997, by R.K.Mohapatra and S.V.S.Murty.
  198. " $^{207}\text{Pb}/^{206}\text{Pb}$  Zircon Ages of Samples from the Bundelkhand Massif, Central India", International Conference on Isotopes in the Solar System, **Ahmedabad**, November 11-14, 1997, by M.E.A.Mondal, M.P.Deomurari, J.N.Goswami, A. Rahman and K.K.Sharma.
  199. "Ancient Martian Atmospheric Signatures from the Antarctic meteorite ALH84001", National Space Science Symposium, **Ahmedabad**, November 25-28, 1997, by S.V.S.Murty and R.K.Mohapatra.
  200. "Nitrogen and Xenon Components in Acapulco Meteorite", International Conference on Isotopes in the Solar System, **Ahmedabad**, November 11-14, 1997, by S.V.S.Murty.
  201. "The Exposure History of Piplia Kalan Eucrite", Annual Meeting of Meteoritical Society, **Hawaii**, July 21-25, 1997, by S.V.S.Murty, N.Bhandari, K.M.Suthar, A.D.Shukla, G.M.Ballabh, M.S.Sisodia and V.K.Vaya.
  202. "Climatic Variations during the Last Glacial Stage : Signatures from Varve Deposits at Goting Garhwal Himalaya", International Conference on Isotopes in the Solar System, **Ahmedabad**, India, November 11-14, 1997, by R.K. Pant, N. Juyal, S.K. Bhattacharya, M.G. Yadava, P. Ghosh, S. Singhode and Rautela.
  203. "How Many Nitrogen Components are Present in Ureilites?", International Conference on Isotopes in the Solar System, **Ahmedabad**, November 11-14, 1997 by V.K.Rai and S.V.S.Murty.
  204. "Nitrate, Non-sea-salt Sulphate and  $^{210}\text{Pb}$  in the Aerosols over the Central Eastern Arabian Sea", 10th National Space Science Symposium, PRL, Ahmedabad, India, November 25-28, 1997, by R. Rengarajan, M.M. Sarin and S. Krishnaswami.
  205. " $^{26}\text{Al}$  and  $^{41}\text{Ca}$  in the Early Solar System : Constraint on Possible Source(s)", International Conference on Isotopes in the Solar System, **Ahmedabad**, November 11-14, 1997, by S.Sahijpal, K.K.Marhas and J.N.Goswami.
  206. "Isotopic and Trace Element Abundances in Hibonites from Murchison Meteorite Devoid of Radiogenic Mg and K Excesses", Lunar and Planetary Science Conference, **Houston**, March 17-21, 1998, by S.Sahijpal, A.M. Davis and J.N. Goswami.
  207. "Low Latitude Cooling across Eocene-Oligocene Boundary: Oxygen Isotope Evidence from Kutch Palaeogene Sequence", International Conference on Isotopes in the Solar System, **Ahmedabad**, India, November 11-14, 1997, by S. Sarangi, A. Sarkar, S.K. Bhattacharya and A.K. Ray.
  208. " $^{210}\text{Po}$  and  $^{210}\text{Pb}$  in the South Atlantic: Distribution and Disequilibria in the Upper 500 Metres", Ocean Sciences Meeting, **San Diego**, USA, February 9-13, 1998, by M.M. Sarin, Guebuem Kim and T.M. Church.

209. "<sup>234</sup>Th Scavenging and Particle Export from the Upper Arabian Sea : JGOFS Results", IAMAS/IAPSO Symposia, Melbourne, **Australia**, July 1-9, 1997, by M.M. Sarin, R. Rengarajan and V. Ramaswamy.
210. "Determination of Organic Carbon and Nitrogen in Marine Sediments using Elemental Analyser", Focus Seminar on Recent Advances in Elemental Analysis, BARC, Mumbai, October 23-24, 1997, by M.M. Sarin, R. Bhushan and K. Dutta.
211. "Fluxes of U-Th Series Radionuclides through the Water Column of the Bay of Bengal", International Conference on Isotopes in the Solar System, PRL, **Ahmedabad**, India, November 11-14, 1997, by M.M. Sarin, T. K. Dalai and S. Krishnaswami.
212. "Reactive Radionuclides as Indicators of Particle and Carbon Export in the Arabian Sea", International Conference on Isotopes in the Solar System, PRL, **Ahmedabad**, India, November 11-14, 1997, by M.M. Sarin, R. Rengarajan and V. Ramaswamy.
213. "Uranium in Himalayan Rivers: Sources and Weathering", International Conference on Isotopes in the Solar System, PRL, **Ahmedabad**, India, November 11-14, 1997, by M.M. Sarin, S. K. Singh, S. Krishnaswami and K.K. Sharma.
214. "Eustatic Change, Anoxia and Foraminiferal Extinction across the Eocene - Oligocene Boundary of Kutch, Gujarat : Evidences from REE Geochemistry and Carbon Isotopes", International Conference on Isotopes in the Solar System, **Ahmedabad**, India, November 11-14, 1997, by A. Sarkar, S. Sarangi, S.K. Bhattacharya, H. Ozaki and M. Ebihara.
215. "Globigerinoids Sacculifera in the Margin Sediments of Eastern Arabian Sea - an Index of Monsoonal Activity", Xth National Space Science Symposium, Ahmedabad, India, November 25-28, 1997, by A.Sarkar and B.L.K. Somayajulu.
216. "Carbon and Oxygen Isotopic Studies on Carbonatites of Samchampi Alkaline Complex, Karbi Anglong District, Assam, India", International Conference on Isotopes in the Solar System, PRL, Ahmedabad, November 11-14, 1997, by S.K. Sengupta, J.S. Ray, S. Rahman and S. Nag.
217. "Chemistry and Petrography of the Piplia Kalan Eucrite", Annual Meeting of the Meteoritical Society, **Hawaii**, July 21-25, 1997, by A.D.Shukla, N.Bhandari, P.N.Shukla, R.Natarajan, V.K.Vaya and M.S.Sisodia.
218. "Implications of the Triple Iridium Anomaly in the Anjar Intertrappeans to the K/T Boundary Problem" International Conference on Isotopes in the Solar System, **Ahmedabad**, November 11-14, 1997, by P.N.Shukla, A.D.Shukla, R.Ramesh, K.Pande, T.R.Venkatesan and N.Bhandari.
219. "Positive Europium Anomaly in the Permian-Triassic Boundary in Lalung and Guling Sections of Spiti, India", International Conference on Isotopes in the Solar System, **Ahmedabad**, November 11-14, 1997, by P.N.Shukla, N.Bhandari, K.M.Suthar and R.J.Azmi.
220. "Accelerator Mass Spectrometry (AMS) in Oceanography", VIIIth ISMAS Workshop on Mass Spectrometry, Bhabha Atomic Research Centre, Mumbai, India, August 4-9, 1997, by B.L.K. Somayajulu.
221. "Circulation in the Arabian Sea using Carbon-14", in IAMAS-IAPSO Joint Assemblies, Melbourne, **Australia**, July 1-9, 1997, by B.L.K. Somayajulu, R. Bhushan, S. Krishnaswami and P.V. Narvekar.
222. "IGBP and Oceans", Indian National Science Academy (INSA), Seminar on Present Trends and Future Directions in Ocean Science, INSA, New Delhi, India, October 6-7, 1997, by B.L.K. Somayajulu.
223. "Some Aspects of the Geochemistry of Estuaries", National Symposium on Coastal and Estuarine Processes around India, Andhra University, Visakhapatnam, September 10-11, 1997, by B.L.K. Somayajulu.
224. "Sr Isotope Studies of the Lesser Himalayan Carbonates : Implications to <sup>87</sup>Sr/<sup>86</sup>Sr of the Ganga-Ghaghara-Indus Source Waters", International Conference on Isotope in the Solar System, **Ahmedabad**, November 11-14, 1997, by Sunil K. Singh, J.R.Trivedi, K.Pande, R.Ramesh and S. Krishnaswami.
225. "Geochemical and Geochronological Studies of Granitoids of Eastern Karakoram and their Impact

on the Tectonic Interpretation", International Conference on Isotopes in the Solar System, **Ahmedabad**, November 11-14, 1997, by A.K. Sinha, J.R. Trivedi, R. Upadhyay, H. Rai and R. Chandra.

226. "Palaeoclimate and Palaeovegetation of the Indo-Gangetic Plain during the Plio- Pleistocene Period Inferred from the Pedogenic Carbonates of the Siwalik", International Conference on Isotopes in the Solar System, **Ahmedabad**, India, November 11-14, 1997, by J.V. Thomas, S.K. Bhattacharya, R.A. Jani, R. Mohindra and B. Prakash.

227. "Occurrence of Uranium in Sambhar Salt Lake,

Rajasthan (India): Implications to Source of Salt", International Conference on Isotopes in the Solar System, PRL, **Ahmedabad**, India, November 11-14, 1997, by D.N. Yadav, M.M. Sarin and S. Krishnaswami.

### **Electronics Laboratory**

228. "Hand-written Character Recognition using Neural Network", National Seminar on Neural Network , July 21-23, 1997, by H. S. Mazumdar.

229. "Sports with High-tech", Seminar on Good Aports Person, A Scientific Commodity, September 13-14 1997, by H.S. Mazumdar.



**Science  
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The Astronomy and Astrophysics Division is located in a campus at Thaltej (7 Kms from PRL). At Mt. Abu an infrared observatory with a 1.2m telescope and a host of back-end instruments like photometers, polarimeters, CCD camera etc. cater to the observational needs of the astronomers. This year, a state of the art instrument - IR Array has been added. This has enhanced the capability of the IR telescope. At Udaipur Solar Observatory (USO) the observations on Sun are being carried out using three solar telescopes. A GONG experiment is operating to study the solar oscillation modes and to probe the interior of the Sun using helioseismology.

## **Time Variability of Polarization in BL Lac Objects: OJ287, Mrk421, Mrk501**

BL Lacertae objects OJ287, Mrk421 and Mrk501 were monitored for studying short time scale variability using PRL Photopolarimeter. Some of the results are presented here. It is found that variability exists on various time scales in the sources studied. In case of Mrk 421 and Mrk 501, the polarization (during January to May 1997) is found to be relatively higher compared to the normal values reported earlier for these sources. It appears that there is a correlation between the gamma-ray burst detected in Mrk 421 earlier last year and the increase of polarization in the optical region. Monitoring of some of the sources is being done simultaneously in  $\gamma$ -ray by BARC group and in optical by PRL group.

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

## **Photometric Studies of Starburst Galaxies**

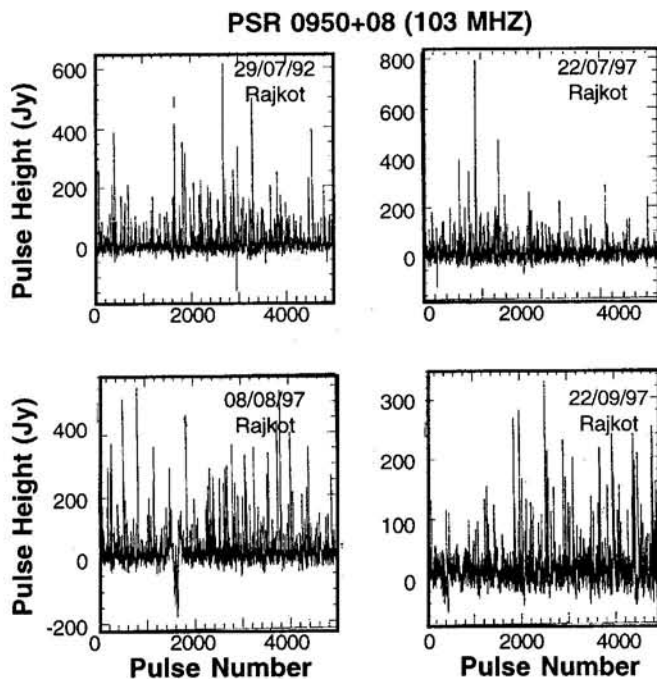
A sample of starburst galaxies selected from the Markarian catalog has been observed on the 1.2m Mt. Abu telescope as a part of long term program of studying starburst galaxies. These galaxies are undergoing a burst of intense star formation as a result of which they appear bluer for their morphological types. UBVRI and H- $\alpha$  imaging of this sample has been done using a 1K X 1K CCD camera. We find that starburst activity is seen in a variety of morphological types. The star formation centers are traced using the color maps. It has been found that the enhanced star formation is not always confined to the

nuclear region but it is also found at the ends of bars or at the location of the resonances in barred spirals. Images in JHK band have been obtained for some of these galaxies using the NICMOS 3 camera on 1.2 m telescope. The data in UBVRI JHK bands will help us to constrain the models of starburst galaxies.

(Aparna Chitre, U.C. Joshi, A. B. Shah, N. M. Vadher and M. R. Deshpande)

## **Giant Pulsation of PSR 0950+08**

With radio telescopes at Rajkot and Ahmedabad, pulsar observations were carried out and **Giant pulses from PSR 0950+08** were detected on 29 July 1992, for the first time. The observations were continued to see whether the burst can be detected again. After a period of five years very strong burst activity was detected during the month of August 1997. This time the burst activity was more intense and showed variations on day to day basis and lasted for a week (**Fig.1.1**). The activity peaked on August 8, 1997, when the average-pulse intensity was an order of magnitude higher than normal. **At least 100 giant pulses** were seen with intensity in excess of **100 times** the normal intensity. Some of the strongest pulses reached a level 500 times more than the average intensity



*Fig1.1 Burst records of Pulsar 0950+08*

of this pulsar. There have been five events over a period of three months (July-September, 1997). The observations establish that PSR 0950+08 is the most violent giant pulsator.

(Hari Om Vats, A.K. Singal, M.R. Deshpande, Chhaya Shah, K.N. Iyer, Rupal Oza and S. Doshi)

### ***Detection of Radio Pulses from Geminga***

A significant finding has been the direct detection of radio pulses from Geminga pulsar. Geminga is a well known X-ray and gamma ray pulsar, the only pulsar first discovered at any frequency other than radio. On June 19, 1997 our observations of this object at 103MHz showed an evidence of radio pulses from this pulsar. The folding data of the pulsar showed very weak radio pulses from this object and showed that either the period of radio pulses is 118.53msec without any interpulse or 237.06msec with an interpulse of almost the same intensity at 0.5 phase. We are continuously monitoring and analyzing the data. The pulsar is weak and also seems to have a variability which needs to be established. This work was carried out in collaboration with K. N. Iyer and Rupal Oza.

(Hari Om Vats, A.K. Singal, M.R. Deshpande, Chhaya Shah, and S. Doshi)

### ***Imaging and Spectroscopy of Young Stellar Objects (YSO)***

NICMOS 3 array was used to study a few selected molecular cloud complexes in the region of Cassiopeia and Ophiuchus and a few selected YSOs. Imaging of these objects was carried out in J, H, K and K' bands. Narrow band imaging was also done in the emission bands of H<sub>2</sub>, Br gamma, along with continuum. Low-resolution spectroscopy using the grating spectrograph of the NICMOS 3 was done on some selected sources. Some of these objects were also mapped in [SII] 6715 Å line at the 2.34m Vainu Bappu Telescope (VBT) at Kavalur for a better understanding of the excitation processes (shocks or radiation) in collaboration with K.K. Ghosh of IIA.

(B.G.Anandarao, M.S.Nandakumar and R.T.Patel)

### ***Infrared Studies of Young Stars - The Herbig Ae/Be stars***

The Herbig Ae/Be stars (mass range 2-8M<sub>⊙</sub>) are associated with nebulosity and emission lines and likely to be approaching main sequence. They show evidence for circumstellar shells, mass outflow and irregular variability suggesting that these stars are young. These stars are strong infrared sources and presently this is included as one of the properties of Herbig stars. Though it is known that Herbig Ae/Be stars exhibit rapid and irregular variability very few systematic studies have been done. We have initiated a programme to obtain homogeneous set of photometric and spectroscopic data to look for trends in the amplitudes of variability. Our observations taken during November and December 1997 using the NICMOS-3 IR Array clearly show strong variations in the emission line fluxes of the Herbig star AB Aurigae. Harish C. Bhatt of IIA is participating in this programme.

(N.M.Ashok and T. Chandrasekhar)

### ***Detection of Circumstellar Dust Around the Final Helium Shell Flash Object V4334 Sagittarii***

Sakurai's peculiar variable in Sagittarius, V4334 Sgr, underwent a final helium shell flash and brightened in a nova-like fashion during 1995-96 to become a born again asymptotic giant branch (AGB) star. We have observed this unique object in the JHK bands from Mt. Abu and our data reveals a large increase in the near IR flux because of a dust condensation episode seen about two years after the outburst. About  $4.5 \times 10^{-10} M_{\odot}$  of dust condensed around the star at a temperature of 1900K. The mass of V4334 Sgr has been estimated to be about 0.8 M<sub>⊙</sub> and its radius as 70 R<sub>⊙</sub>.

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

### ***Polarimetric Study of Sakurai's Object***

Polarization observations of Sakurai's object were carried out in BVRI bands using PRL photopolarimeter and 1.2 m telescope. The polarization appears to increase from B band to V band, then decreases in R band and again increases in I band. The polarization angle remains nearly the same (within the error bars) in all the



bands. The nature of the polarization can not be explained in terms of a single component model. Two component model is more appropriate to explain the polarization behaviour. The photometric data also support the two component model. This work was carried out in collaboration with N. Kameswara Rao IIA.

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

### ***Optical and Near-infrared Studies on Planetary Nebulae and Post-AGB Stars***

The physical processes responsible for the formation of PNe predict a higher mass loss rate for Contact Binary (CB) systems (through the common envelope (CE) ejection) than for the single stars or Detached Binary (DB) systems (through superwind). Assuming a simple hydrodynamical model, we have shown that this difference in mass loss rates translates into a lower nebular expansion velocity ( $V_{\text{exp}}$ ) for the CB systems than for the other class. A compilation of the available  $V_{\text{exp}}$  observations (though limited) of PNe with known/suspected binary central stars seems to uphold the theoretical predictions. This result has a specific significance in that it can be used as a guideline for future high spatial resolution observations to detect possible companions of planetary nebulae central stars.

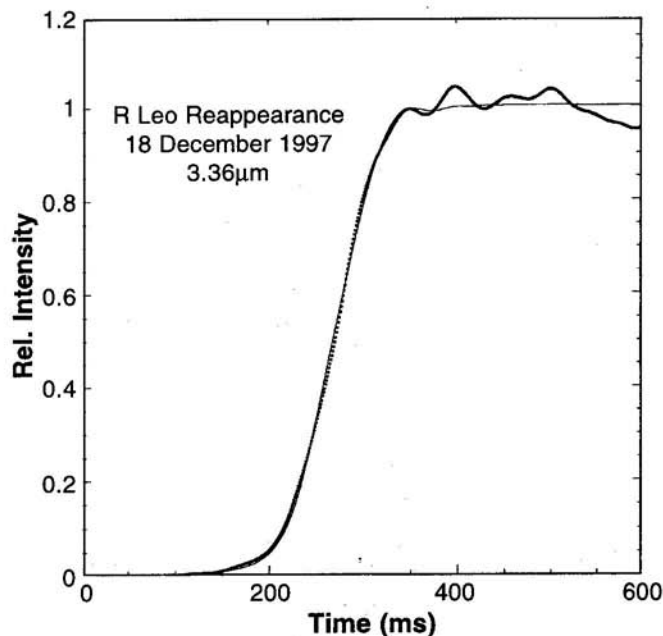
For a detailed kinematic study, we have selected NGC 246, 1514, 2610 and 4316 with confirmed or suspected CB central stars and mapped them in the [OIII] (5007 Å) line. Some of these observations were made with seeing-limited resolution for velocity mapping at Mt. Abu observatory. The PN NGC 246 is morphologically peculiar and is probably strongly interacting with the interstellar medium as indicated by the sharp rims towards the west side of the nebula. This nebula showed a maximum  $V_{\text{exp}}$  of 44 km/s near the central star. The  $V_{\text{exp}}$  decreased radially towards regions with high density clumps present in the interaction zone. The decrease in  $V_{\text{exp}}$  is not as marked in the other low density regions. We believe, therefore, that our results indicate for the first time a deceleration of expansion caused by the Interstellar medium. The clumpyness in the interaction zone could be due to the growth of Rayleigh-Taylor instability.

Further, we have initiated a programme to map the molecular hydrogen regions surrounding the PNe in the near-infrared bands, using the newly-acquired NICMOS 3 IR array camera. These regions will be compared with maps of ionized regions as traced out by the Bracket gamma line observations to determine whether the nebulae are ionization/density-bounded. The analysis is being done on a few nebulae on which observations have recently been made.

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

### ***Angular Size of Mira Variable R Leo***

The detailed understanding of observable properties of long period variable stars (LPV) are complicated by the need to take into account simultaneously several factors like pulsations, radiation transport, molecule and grain formation. In a recent initiative the phase and cycle dependence of observable properties of Mira variables like spectrum, colors, absorption line profiles are being investigated. Use of temporal changes of apparent angular size of Mira variables has been largely unexplored. A lunar occultation of the bright Mira variable R Leo was observed on 18 December 1997 (**Fig.1.2**). The reappearance



**Fig.1.2** Reappearance occultation of the Mira variable R Leo at 3.36 microns on 18 December 1997

ance event was observed at 3.36 microns with a bandwidth of 0.05 microns using the transmission channel of the two channel IR fast photometer. Analysis shows that the angular size is  $35 \pm 4$  milliarc seconds. A subsequent occultation of R Leo in March 1998 was clouded out but could be observed under difficult conditions at Calar-Alto Observatory (Spain) in the K band (2.2 microns). Since the 82 day separation between the two events is a significant fraction of the 313 day period of variability of R Leo, a detectable variation in angular size is expected and is being investigated. During this period circular variable filter observations of R Leo have been made. Also observations have been made using the Infrared array detector in the spectroscopy mode.

(T.Chandrasekhar, Anandamaye Tej, N.M. Ashok and Soumen Mondal)

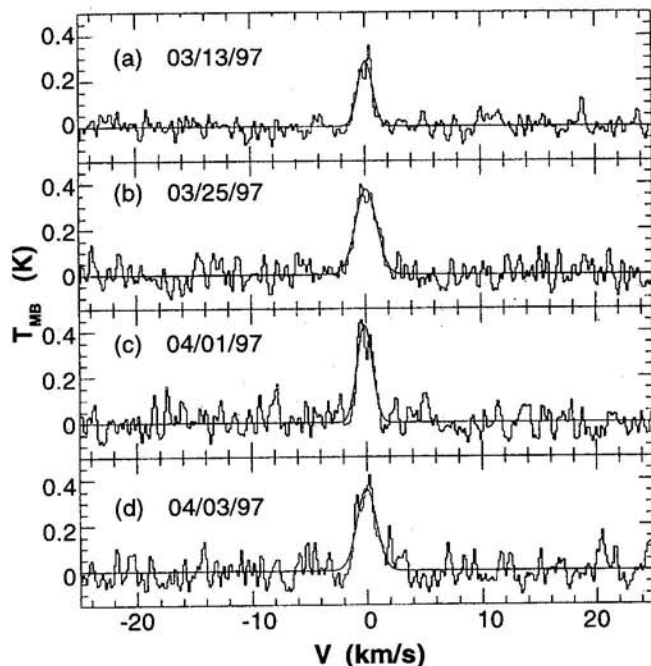
### **K-Band Radio Observations of Comet Hale-Bopp**

K-band radio observations of comet Hale-Bopp (C/1995 01) were conducted in March/April 1997 at the 100m Telescope of the Max-Planck-Institut für Radioastronomie. Emission was firmly detected from the five lowest metastable ( $J=K$ ) inversion transitions of ammonia (**Fig.1.3**). Assuming a thermal distribution for the metastable states of  $\text{NH}_3$ , we derive a rotational temperature of  $104 \pm 30$  K and an ammonia production rate at perihelion of  $6.6 \pm 1.3 \times 10^{28} \text{ s}^{-1}$ . The updated ammonia-to-water abundance ratio is found to be of the order of 1.0%. A marginal detection of the  $6_{16}-5_{23}$  transition line of water at 1.35 cm was also made. This work was carried out in collaboration with M.K.Bird of Radioastronomisches Institut, Bonn, Germany.

(P. Janardhan)

### **Wide Field Imaging Polarimetry of Comet Hale-Bopp**

Comets offer an excellent opportunity to study the gas and dust within and outside the solar system. In an innovative way, wide field Imaging polarimetry of comet Hale-Bopp was carried out on 7 April 1997 in the Johnson's R broad band. A liquid nitrogen cooled 1 K x 1K CCD camera equipped with R band filter and a 400 mm focal length Canon Zoom lens mounted on an equatorial



*Fig. 1.3  $\text{NH}_3(3,3)$  spectra from comet Hale-Bopp during the four observation days*

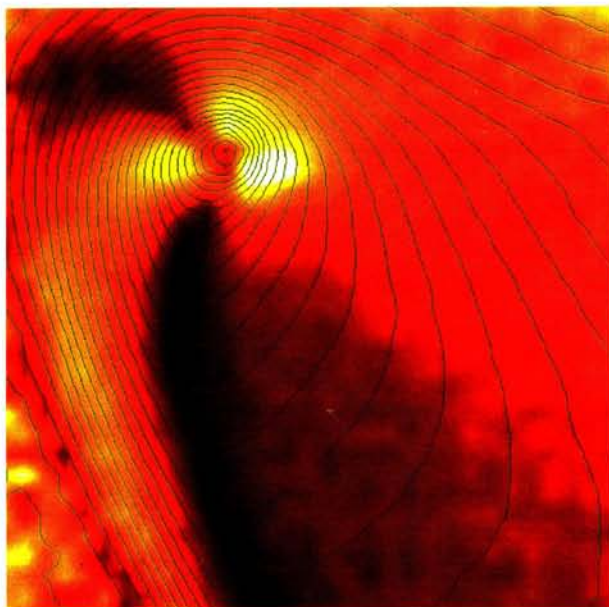
sidereal drive, was used for imaging the comet. A polaroid sheet mounted in a slide, having provision to rotate it through 45 deg steps in front of the zoom lens was used to obtain the polarization information. The experiment was conducted to study the polarization map over a large field. The field of view covered by this wide-field camera is nearly 7 degrees.

Polarization vector maps and the intensity images show various features in the comet (**Fig.1.4**). The polarization is found to be higher along the jets and also shows a gradient along and across the tail. The higher polarization along the jet can be explained in terms of higher concentration of small dust particles along the jet.

(S. Ganesh, U.C. Joshi, M.R. Deshpande, N.M. Vadher, A.B. Shah and S.N. Mathur)

### **Imaging Polarimetry of Comet Hale-Bopp**

Imaging polarimetry of the coma of C/1995 01 (Hale-Bopp) was carried out on 9 May 1997 in the near infrared (8000 Å to 10000 Å wavelength band). A CCD camera having a Tektronics 1K X 1K thinned back illuminated detector was used. High polarization is found



**0% Polarization Scale 39%**  
 Fig.1.4 Polarisation map of Comet Hale-Bopp. Contours of the intensity (log scale) are shown superimposed. Area shown spans 7"x7"

close to the photocenter of the comet which may be due to grain alignment. Polarization is also found to be higher in the jets. There is a low polarization region around the nucleus on the tailward side which is due to non alignment of the grains. Position angle of polarization appears to be uniform over the entire image.

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

### **Photopolarimetry of Comet Hale-Bopp : Grain Properties**

High precision polarization observations to study wavelength dependence of polarization over a wide range of phase angles varying from  $17^\circ$  to  $47^\circ$  were made of the coma region of comet Hale-Bopp using the 1.2M telescope at Mt. Abu Observatory. Detailed continuum linear polarization data provides an opportunity to deduce the dust grain properties such as shape, size, their distribution and refractive indices. Usually at small phase angles ( $< 20^\circ$ ) polarization is parallel to the scattering plane (referred to as negative) while at larger phase angles it is perpendicular to the scattering plane. The

cross over region is very sensitive to the nature of dust grains and grain size distribution. A theoretical model based on Mie scattering is used to fit the observed high continuum polarization in the coma region of the comet Hale-Bopp. It shows that grain size distribution for comet Hale-Bopp is quite different (finer grains) from that of comet Halley and comet Hyakutake. High polarization and strong wavelength dependence of the polarization observed in this comet indicate that this comet has finer grains than that of comet Halley.

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

### **Mg V Collisional Excitation Data of Interest in Solar Study**

Many Mg V excitation lines have been observed with the instruments on board SOHO satellite. Some other lines were reported in the high excitation planetary nebulae. Unfortunately, accurate absorption oscillator strengths and excitation cross sections on most of these lines are either non-existent or are of very poor quality. The reason being that calculation is rather complicated and requires sophisticated techniques to get reasonably good quality data. Due to their importance in heating-cooling mechanism of sun's atmosphere, we decided to calculate such data on Mg V transitions. Configuration-interaction wavefunctions are constructed and close coupling R-matrix technique is used for the calculation. The lowest fourteen target states of  $\text{Mg}^{4+}$  are constructed using six atomic orbitals. The parameters for these orbitals are obtained variationally. All these states are retained in the total wavefunction expansion. The collision strengths are calculated for all the transitions involving these states upto three Rydberg incident electron energy. The work is being done in collaboration with NASA/GSFC.

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

### **PRL Near Infrared Camera - Detector Noise Characteristics**

Recently the Division has acquired Near Infrared Camera NICMOS 3. The array has 256 X 256 pixels of HgCdTe. The wavelength range covered by the detector



is from 0.8 to 2.5 micron. Imaging in the J, H, K and K' filters and also several narrow band filters within the above spectral range is possible with this camera. In addition to imaging the camera also has facilities for multi-object spectroscopy as well as imaging polarimetry. The array characteristics were studied and evaluated in-house and parameters such as the dark noise, gain, read noise, linearity etc. were estimated. For readout purpose, the camera is divided into four quadrants (with independent readout circuits). The gain and readnoise were found to be nearly same in all the quadrants while the dark current was found to be quite different in the four quadrants - varying from 15 e/sec in one quadrant to a maximum of 82 e/sec in another. Non-linearity is found at low signal levels upto 1000 Analog to Digital Unit (ADU). The characteristic curve again departs from linearity beyond a signal level of 12000 ADU.

(U.C. Joshi, S. Ganesh, A.B. Shah, N.M. Vadher, A. Chitre, Chhaya Shah, V.D. Patel and M.R. Deshpande)

### ***Improving the Accuracy of the Caustic Test***

The Caustic test, commonly used to test the primary aspheric mirror of telescopes, has been studied with reference to the work of Schroader. It is shown that the two central formulae, which are used to determine mirror quality, give significant errors for small f-ratio mirrors commonly used in astronomical optics. We have derived analytically two alternative equations, which are exact, and show that they lead to significant improvement. This work was done in collaboration with R.V. Willstrop, Institute of Astronomy, Cambridge.

(D.P.K. Banerjee and B.G. Anandarao)

### ***Fractal and Correlation Study of Solar Radio Emission***

Solar radio emission originates in the plasma of the outer atmospheric layers, the chromosphere and corona. Fractal analysis of radio emissions from Sun revealed that the fractal dimension is least around 2.8 GHz indicating that emission around this frequency is least affected by the medium turbulence. Thus we used radio emissions around 2.8 GHz as a diagnostic for solar coronal rotation. Our study shows that the mean solar sidereal rotation for

cycle 22 is 24.73 days. This indicates that the corona rotates faster than photosphere. The work also establishes that different parts of solar corona have differential rotation. A temporal variation in the rotation of solar corona at all heights is evident.

(Hari Om Vats, M. Mehta, K.J. Shah and Chhaya Shah)

### ***Application of Diffractive-Refractive Scattering to IPS***

Study of the structure and dynamics of the solar plasma is being pursued by IPS method. We recently incorporated an approach based on the diffractive-refractive scattering for the first time in the analysis of IPS observations and derived the parameters of the interplanetary medium. This scattering approach was successfully used earlier by us for the investigations of radio propagation in the ionosphere and laser propagation in the lower atmosphere. The solar wind speed is used to calculate solar plasma acceleration which is found to be in the range of 4 to 25 ms<sup>-2</sup>. These measurements will be useful in the model of solar corona. This work was carried out in collaboration with Rupal Oza, K.N. Iyer and M. Mehta of Saurashtra University, Rajkot.

(Hari Om Vats and M.R. Deshpande)

### ***Propagation of Solar Plasma Disturbances in the IPM***

Solar energetic events are investigated in a campaign mode using both the national and international facilities. Three energetic events, namely, 30 September, 1993; 6 January, 1994 and two ribbon flare of 12 May, 1997 are analysed in detail. These collaborative investigations bring out the following features: (1) The plasma disturbances associated with solar burst and flare may cause about 40 times enhanced turbulence in the interplanetary medium, however, it will be varying from event to event; (2) Event though the events on Sun may be very short lived their effects in the interplanetary medium and terrestrial environment may last for few days; (3) During the two ribbon flare there is a clear evidence for reconnection of the loops and the emerging magnetic flux regions. The maximum magnetic field strength calculated

on the basis of cyclotron mechanism turns out to be about 1900 G and (4) shock speeds of the plasma disturbances are estimated to be in the range of 500-1000 km/sec. This work was carried out in collaboration with K.N. Iyer of Saurashtra University, Rajkot.

(Hari Om Vats, M.R. Deshpande, R. Jain, H. Chandra and S. Sharma)

### ***Solar Wind Observations Close to the Sun using Ulysses Sounding Data***

A well-known method for studying the solar wind very close to the Sun (heliocentric distances: 4 to 40 solar radii) is by radio sounding between a spacecraft at superior conjunction and the Earth. The Ulysses Solar Corona Experiment was performed at the spacecraft's two solar conjunctions in summer 1991 and winter 1995, during which dual-frequency ranging and Doppler observations were conducted globally on a nearly continuous basis at the NASA Deep Space Network and other ground stations. The dual-frequency Doppler data were used to determine coronal plasma velocities by a cross correlation analysis on all occasions when data were obtained simultaneously from different well-separated ground stations. Because the data, particularly at small solar offsets, can be heavily contaminated by noise, a technique of "filtering" was developed and used to enhance the 2-station correlations. Electron content measurements during the two solar conjunctions show that the peaks in the electron density correlate with slow velocities. This work was carried out in collaboration with M.K. Bird of the Radioastronomisches Institut, Bonn, Germany.

(P. Janardhan)

### ***Radiation from a Uniformly Accelerated Charge***

First time an analytical method has been found for calculating the total energy in the electromagnetic fields of an accelerated charge. From that it has been shown that the total energy in electromagnetic fields of a uniformly accelerated charge is just equal to the self-energy of a non-accelerated charge moving with a velocity equal to the instantaneous *present* velocity of the accelerated charge. This unambiguously shows that a uniformly accelerated

charge does not emit electromagnetic radiation, in contrast to what generally is believed.

(A.K. Singal)

### ***Photospheric, Chromospheric Activities and Magnetic Fields Associated with a Large Flare and Filament Eruption of September 29, 1991***

A large filament eruption, followed by a M7.3/4B class flare, was observed on September 29, 1991/15:13 UT in NOAA AR6850. Although strong magnetic fields, gradients, electric currents, and shear are generally associated with locations of large flares, this particular flare occurred in a site of weak magnetic fields and low shear. The filament showed significant pre-flare activity as seen from the chromospheric H-alpha observations. The observed transverse magnetic field azimuths exhibited rapid changes. It is suggested that these changes ultimately led to the destabilization of the filament, and that the energy stored in the sheared dark filament fed the flare. We examine the photospheric and chromospheric activities in association with the magnetic field changes, prior to the onset of the filament eruption. We also report the observation of magnetic shear variation during the course of the flare. The roles of vertical currents, and corresponding Lorentz forces are studied for this flare.

(Ashok Ambastha and Debi Prasad C.)

### ***Daily Evolution of Active Regions and Emerging Flux Regions***

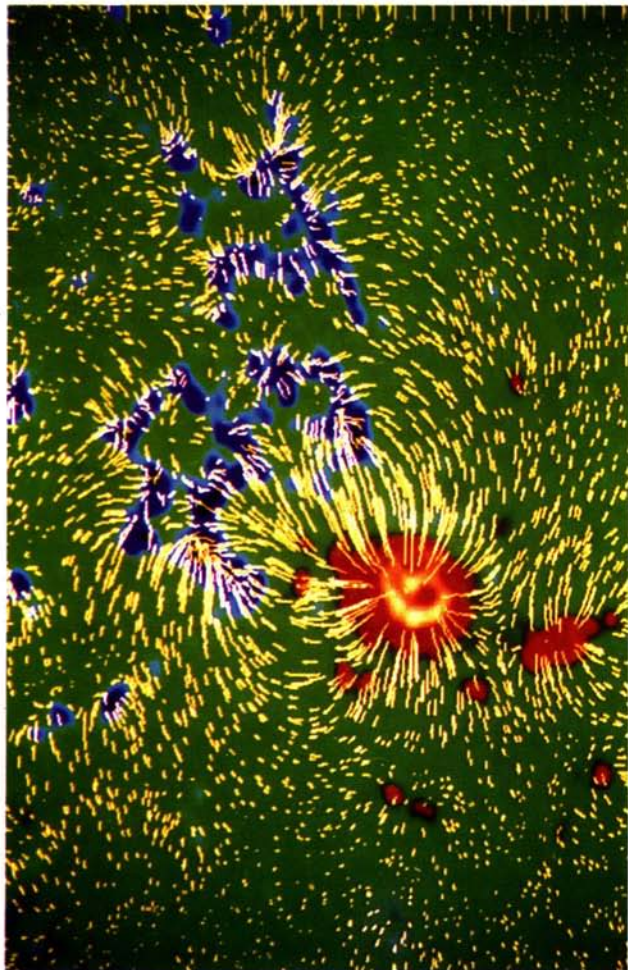
Daily evolution of solar active regions was studied using the longitudinal magnetograms, H-alpha and Ca I images obtained at Udaipur Solar Observatory. Active regions AR 7843, AR 8032 and AR 8038 were observed during February 18-20, 1995, April 15, 1997, and May 10-13, 1997 respectively. Flares and surges of the moderately active AR 7843 were observed. We have developed an IDL software for the calculation of potential field using Schmidt technique. The comparison of potential field with the chromospheric H alpha fibril structures gives a qualitative measure of magnetic shear, which is an important parameter for predicting flare occurrence.

(Shibu K. Mathew and Ashok Ambastha)



### ***H-alpha and Hard X- ray Flares of April 13, 1980***

A series of small to moderate size of H-alpha flares were observed on April 13, 1980, in Hale AR No. 16747 and 16752 near the solar limb. SMM/HXRBS recorded a series of hard X-ray flux enhancements in the energy range 26-470 keV associated with these flares. Growth and intensity characteristics of the flare kernels have been obtained from the analysis of the H-alpha images.



*Fig. 1.5 USO Solar Magnetogram of NOAA AR 8038 of May 11, 1997 - The calculated transverse component of the potential field is superimposed as line-segments, over the observed map of the longitudinal magnetic field (red-positive polarity, blue-negative polarity flux)*

We found that the kernels were associated with HXR emission in 15 different energy channels. In particular, two flares were found to be of specific importance in the context of hard X-ray emission at energies  $> 50$  keV. The first flare in Hale active region 16747 showed steep fall in flux around the flare peak time. On the other hand, the second flare in Hale active region 16752 showed large flux around its peak time. This indicates that in the case of the second flare, the electrons penetrated much deeper in the chromosphere, emphasizing stronger acceleration at the flare onset time. This work was carried out in collaboration with B.R. Dennis.

(Rajmal Jain, Lokesh Bharti and Nirav Mehta )

### ***Multi-Spectral Observation of the Flare Activity in NOAA 8038***

We have analysed photospheric, chromospheric and high resolution magnetogram observations of NOAA active region No. 8038 taken at USO during 10-13 May, 1997 (**Fig.1.5**). We present an evidence for the interaction of the emerging flux with the pre-existing fluxes, leading to accumulation of energy for a moderate 1B/ C1.3 flare of 12 May, 04:45UT. USO optical observations in association with hard X-ray and radio observations showed at least two phases of energy release at 04:42 and 04:48 UT. We have developed a model to explain the multi-spectral observations of the flare, observed bright mass ejection at the flare onset, type II radio burst, associated coronal mass ejection (CME) and later enhancement in scintillation as measured by Interplanetary scintillation array at Rajkot. This work was carried out in collaboration with special Astrophysical Observatory, USSR, Hiraio Solar-Terrestrial Research Centre, Japan and Saurashtra University, Rajkot.

(Rajmal Jain, Nirav Mehta, Hari Om Vats, M.R. Deshpande, Shibu K. Mathew and H. Chandra)

### ***Mid-UV Solar Variability During the Descending Phase of Sunspot Cycle 22***

The Sun Backscatter Ultraviolet (SBUV/2) instruments onboard NOAA-11 satellite measured solar spectral UV irradiance during the maximum and declining



phase of solar cycle 22 in the range of 170 - 400 nm at steps of 1 nm. This data has been used to obtain UV variability in general and at a few identified lines such as Mg I (285.16 nm); Mg II (279.54 - 280.23 nm); Si I (288.11 nm); Fe I (358.12 , 373.48 nm); Ca K (393.36, 396.84 nm); Ni XIII (212.6 nm); Si IX (214.95 nm), in particular. The preliminary analysis of 898 days data revealed that irradiance varied by about 7% at 200 nm, and by 1% at 300 nm from sunspot minimum to maximum period. The irradiance variation below 280 nm shows the periodicities of 27 and 13 days. The power spectrum of a few identified lines, Ni XIII, Si IX, Fe XII and Mg I show periods of 13, 27, 75 and 155 days. The predominant period of 27 days refers to solar rotation, which was found to change from 25 to 29 days during 1989 to 1994, the descending phase of solar cycle 22. The periodicities of 13 and 27 days are prominently seen below 280 nm such as in the case of Ni XIII and Fe XII. However, above 280 nm, irradiance from photosphere contributes significant noise in the signal but longer periodicity of 75 and 155 days becomes more prominent as seen in Mg I and Fe XIII. This work was carried out in collaboration with R.P. Cebula and Kandarp Bhatt.

(Rajmal Jain and Lokesh Bharti)

### ***Seismic Estimate of Solar Radius: Possible Systematic Errors***

Possible systematic errors in determining the solar radius from the f-mode frequencies are investigated. It is inferred that the input physics governing the structure of outermost layers of the Sun has significant influence on the estimated radius. Since the f-modes are localised just below the solar surface, their frequencies depend to a small extent on the density stratification and are affected by the convection and opacities. Thus, role of convection and low temperature opacities on the measurement of radius is explored. We find that the estimated radius can be affected by about 100 km. The best estimate of the solar radius is found to be  $695.77 \pm 0.1$  Mm, where the error bars represent estimate of systematic errors. This work was done with H.M. Antia, TIFR, Mumbai.

(S.C. Tripathy)

### ***Asteroseismology of the Delta Scuti Stars in Praesepe Cluster***

Mode identification of Delta-scuti stars are very difficult. Thus, it was proposed to carry out observation of two Delta-scuti stars BN Cnc and BV Cnc in the Praesepe cluster during January -April 1998 as a part of the global campaign under the program of Small Telescope Array of CCD Cameras (STACC). In this connection, four nights of photometry data has been taken from Mt. Abu Observatory using the 1.2 m telescope. We plan to identify various modes and their frequencies for these stars to put constraints on the stellar models.

(S. C. Tripathy, U.C. Joshi, Rajmal Jain and M.R. Deshpande)

### ***Sensitivity of the Solar Neutrino Flux to Opacity Changes***

The sensitivity of the solar neutrino fluxes to localised opacity changes is investigated by constructing standard solar models of the Sun. Since the production of high energy neutrinos are strongly coupled to the core temperature, a slight decrease in the neutrino flux is observed for those models where the central temperature decreased due to opacity changes. Neutrino flux kernels related to the opacity changes are also evaluated to investigate the reproducibility of effect of large opacity changes on the solar structure.

(S.C. Tripathy and K. Jain)

### ***Study of Solar Mean Flows From GONG Data***

The GONG Dopplergrams are a good source of information on solar steady flows. The net flow observed on the solar surface is a sum of solar differential rotation, convective flows, circulations or eddies and the seismic oscillations. The raw GONG data needs to be calibrated, resampled, reduced and mapped into heliographic coordinates before use for any scientific study. In an attempt to study the evolution of the solar mean flows from the refined and heliographic remapped GONG data, we found inconsistencies in the velocity amplitudes from the centre of the disk to the limb. We infer that the "foreshortening" effect persists even after remapping the data into

MEAN POS. & NEG FLOWS -  
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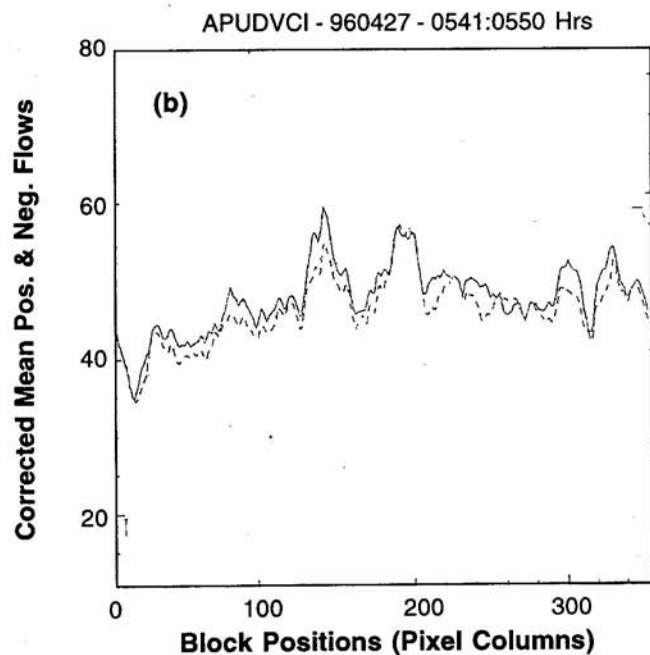
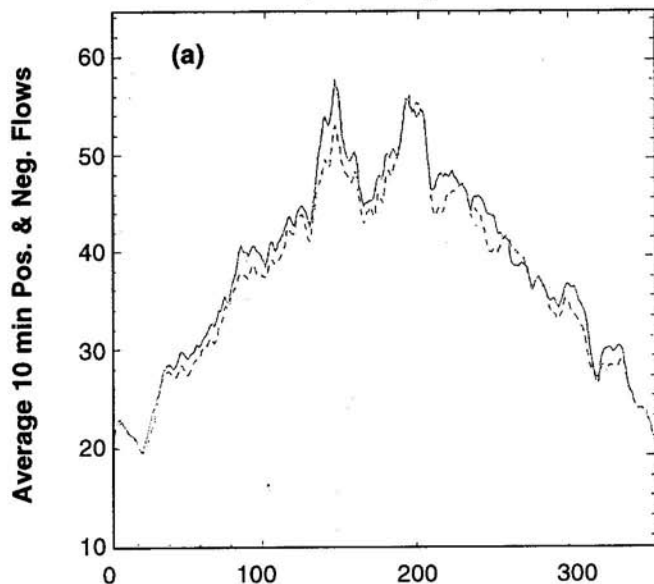


Fig. 1.6 (a) GONG averaged raw velocity profiles over an equatorial slice along the East-West line - solid (dashed) curves represent downward (upward) motion. The steep decrease of the mean velocity is seen toward the E & W limbs, (b) Corrected mean velocity profiles, using the 'secant fit' which clearly reduces the foreshortening effect.

heliographic frame. We have made an attempt to reduce the foreshortening effect by applying a "secant-fit" (Figs.1.6 a, b). The preliminary result seems to be satisfactory. An improved "fit" is being applied for making the data useful for mean flow study.

(Brajesh Kumar, Hari Om Vats, S.C. Tripathy, M.R. Deshpande, K.J. Shah, Chhaya Shah and A. Ambastha)

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: Atomic and Molecular Physics, Gravitation Physics, High Energy Physics, Nuclear Physics, Plasma Physics, Nonlinear Dynamics and Computational Physics.

## GRAVITATION PHYSICS

### ***Ellipticity Behaviour of Rotating Mass Shells***

Continuing the investigation concerning the shape of a rotating configuration in the optical reference geometry we have investigated the ellipticity behaviour of a slowly rotating mass shell (à la Pfister and Braun) for a series of stationary configuration with decreasing radius. The ellipticity first attains a maximum as was in the case of fluid configuration, but then changes sign implying a transition from oblate to prolate shape, and the centrifugal force also shows a change in sign and attains a minimum for a shell with radius close to Schwarzschild radius.

(A. Gupta and A.R. Prasanna)

### ***Rotating Compact Objects with Magnetic Fields***

We have studied the structure of rotating compact objects endowed with a magnetic field in the framework of general relativity as models of pulsars. Using Hartle approach and taking different realistic equations of state we study their effect on bulk properties of neutron star, hybrid star and quark star. We also analyse the magnetic field structure in the interior by integrating the relevant equations from the surface to the centre. We find that the increase in the field strength as one approaches the centre, is more for the rotating case as compared to the nonrotating case for stiffer equations of state. The field strength gets increased upto about 33% due to rotation as one approaches the core, whereas the same at the surface is only about 10%. In the case of hybrid star one does not see any discontinuity in the magnetic field structure at the phase transition region.

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

## **Gravitational Waves**

We have studied gravitational radiation reaction in binary systems, the most likely candidates for the detection of gravitational waves. We had earlier obtained a general formula accurate to 4.5PN order ( $O(v/c)^9$ ) for the radiation reaction. The method used is a refined form of energy and angular momentum balance. We have now extended the analysis to include momentum balance. This gives information on the motion of the individual bodies. This work was done in collaboration with B.R. Iyer and A. Gopakumar, Raman Research Institute, Bangalore.

(Sai Iyer)

### ***Numerical Relativity***

We have studied the evolution of a system consisting of a Schwarzschild black hole and Brill-type gravitational radiation. Radiation of various strengths has been considered. The resulting outgoing gravitational waves are seen to be predominantly at discrete characteristic frequencies known as quasi-normal modes. This study employed a general purpose Numerical Relativity code (Cactus) being developed at the Albert Einstein Institute, Germany. The results were used to compare the new Bona-Masso formulation with the traditional ADM approach. This work was initiated during a visit to the Albert Einstein Institute (AEI) and is a collaboration with the Numerical Relativity group at AEI.

(Sai Iyer)

## **ATOMIC AND MOLECULAR PHYSICS**

### ***First Born Amplitudes for Transition between Arbitrary Excited States of Large (l,m)***

We have developed a method for evaluating the first Born amplitude, in a compact form, for transition between arbitrary excited  $|n_i, l_i, m_i\rangle \rightarrow |n_f, l_f, m_f\rangle$  states of large values of orbital angular momentum and magnetic quantum numbers. We have applied it to evaluate the form factor for transition between arbitrary circular states  $|n_i, l_i=n_i-1, m_i=n_i-1\rangle \rightarrow |n_f, l_f=n_f-1, m_f=n_f-1\rangle$  transition, and have shown that the formula of the first Born



amplitude contains one Jacobi polynomial. For the optically connected ( $n_f - n_i = 1$ ) states, the formula reduces to a simple expression containing the associated Legendre polynomial  $P_{n_i}^1$ . The analytical properties of the first Born amplitude, for example the location of the real zeros, are essentially determined by the known behaviour of the Jacobi polynomial. The formula obtained is also in a form suitable for numerical work.

(D.P. Dewangan)

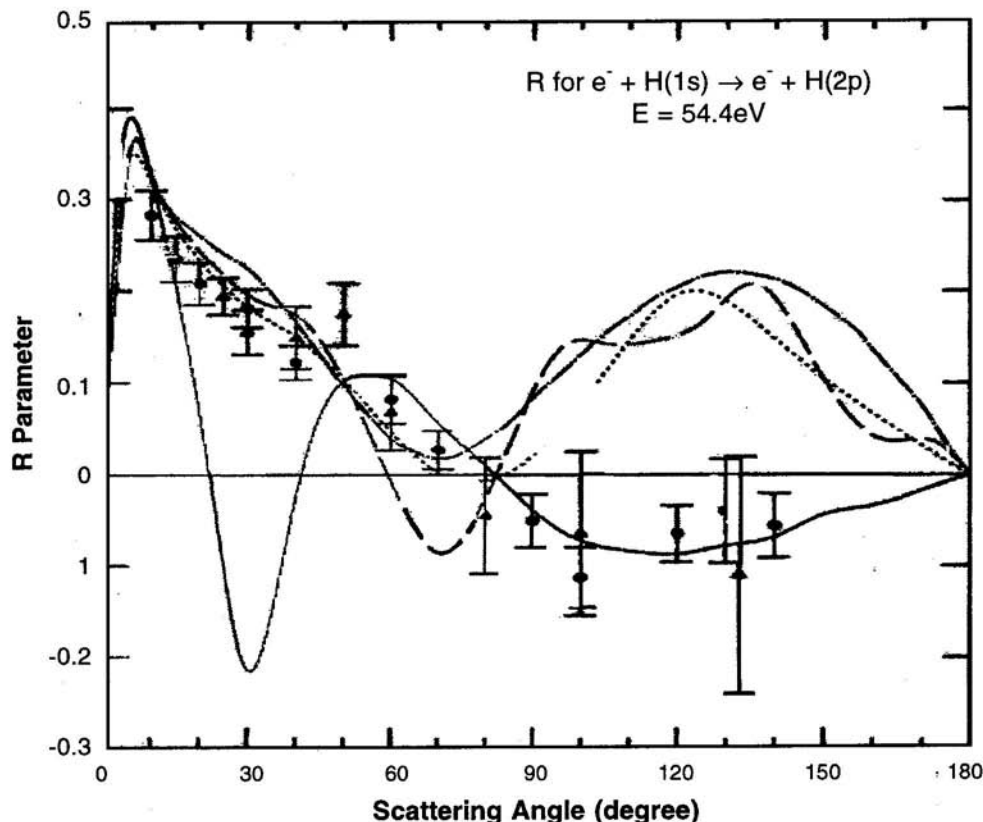
### ***Transition between Excited-States of Atoms Induced by Charged Particle Impact***

In this ongoing project, the main problem arises from the fact that a large number of closely spaced atomic levels lie near both the initial and final excited states, and therefore the couplings amongst these levels must be

included to obtain accurate cross sections. We have developed a multiple scattering model which describes the scattering wave function for the initial channel by a product of two Coulomb waves (TCW model), and whose underlying approximations are well suited for excited-state to excited-state transitions. Now, we have tested the TCW theory for the  $1s$  to  $n=2$  transition and in particular, against the experimental angular correlation parameters for electron impact excitation of  $H(2p)$ .

As the **Fig.2.1** shows, in sharp contrast to existing theories, the TCW theory, for the first time, gives an excellent agreement with the experimental  $R$  parameter for larger scattering angles. We are now computing cross sections for  $n=2$  to  $n=3$  transitions.

(D.P. Dewangan)



*Fig. 2.1 R parameter for the  $1s \rightarrow 2p$  excitation of hydrogen by electron impact at 54. Theoretical results, full curve : the TCW results, other curves are the results of other theories. Experimental results, full circles with error bars : Williams, open triangles with error bars : Weigold et al.*

## HIGH ENERGY PHYSICS

### ***Bilinear R Violations***

Minimal supersymmetric standard model contains soft lepton number violating terms. The importance of including these terms in the analysis of MSSM was highlighted. It was shown that contrary to many claims, these terms have physical significance and lead to number of lepton number violating phenomena. This work was done in collaboration with M. Diaz and J. Valle.

(A. S. Joshipura)

### ***Neutrino Anomalies***

The neutrino anomalies are of great theoretical interest as they provide an indirect evidence for the grand unification of forces. The existing frameworks based on grand unified theories cannot however explain all the known experimental information on neutrino masses. We proposed a modification of the grand unified scenario which does this. This involves a light sterile neutrino. Phenomenological implications of this proposal as well as possible scenario for understanding the lightness and existence of the sterile neutrino in grand unified context were worked out. This work was done with A. Yu. Smirnov.

(A. S. Joshipura)

### ***Charm Squark Interpretation of HERA Events***

We extended our earlier work on the interpretation of possible resonance seen at HERA. Resonant production of charm squark is believed to be one of the plausible interpretation of these events. It was observed in this work that the minimal supersymmetric theory conventionally followed does not allow this interpretation. Some alternative possibilities were suggested. This work was done with V. Ravindran.

(A. S. Joshipura and Sudhirkumar Vempati)

### ***Baryogenesis***

It was proposed by Fukugita and Yanagida that the lepton asymmetry generated in decay of the right handed neutrinos can lead to the presently observed baryon

asymmetry. The calculation of this asymmetry involves unknown parameters related to the right handed neutrinos. This arbitrariness can be removed by using the experimental information from the solar and atmospheric neutrino anomalies. It is shown that these observations as well as available experimental information in laboratory experiments serve to determine parameters of the right handed neutrino mass matrix and hence the baryon asymmetry in a large class of left right symmetric theories. This work was done with E. A. Paschos.

(A. S. Joshipura)

### ***CP-Violating Gluon Couplings to Top Quarks and their Signatures***

The possibility that gluon couplings to top quarks are anomalous and have a CP-violating chromoelectric dipole component has been investigated. Such a coupling would show up in the longitudinal polarization of the top quark or top antiquark in the process  $e^+e^- \rightarrow t\bar{t}$ , together with soft or collinear gluon emission. Specific CP-violating signatures are proposed and the limits on the chromoelectric dipole moment obtainable at a future linear collider have been estimated. This work was done in collaboration with M.M. Tung of State University of New York, Stony Brook, U.S.A.

(S. D. Rindani)

### ***Test of Torsion Background from K Physics***

We show that a background torsion potential gives rise to T and CPT violating potential in the  $K - \bar{K}$  system. From the experimental constraints on T and CPT violations we put bounds on a possible cosmological background torsion.

(Subhendra Mohanty and Utpal Sarkar)

### ***Optical Activity by Space Time Torsion***

We show that in spacetimes with torsion although the covariant Maxwells equations are independent of the torsion field, the covariant electromagnetic wave equation has coupling terms with the torsion field. These arise

due to the non-commutativity of covariant derivatives in spacetimes with torsion. A background torsion field gives rise to a wavelength independent rotation of the plane of polarisation of light signals. Using limits on such anomalous Faraday rotation from observations of radio waves from distant galaxies we put an upper bound on the pseudotrace of the torsion tensor  $|s^\alpha| \propto U_0 \approx \infty \rightarrow \infty$  GeV. This is eleven orders lower than the most stringent of the bounds obtained earlier from neutron interferometry, anomalous Zeeman splitting and  $K\bar{K}$  oscillations.

(Subhendra Mohanty and A.R. Prasanna)

### ***Pair Production of Neutral Fermions by Electromagnetic Fields by the Schwinger Method***

We extend the Schwinger formula for pair production of charged particles in an electric field to particles which may have zero charge but non-zero dipole or anapole form factors. Magnetic dipole pairs are produced in a magnetic field gradient and anapole pairs are produced in a charge gradient. This work was done in collaboration with Eduard Masso and J.A. Grifols.

(Subhendra Mohanty)

### ***Meson Correlators at Finite Temperature***

We 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 modeled using chiral perturbation theory for low temperatures and lattice QCD simulations near the critical 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.

(Varun Sheel, Hiranmaya Mishra and Jitendra C. Parikh)

## **NUCLEAR PHYSICS**

### ***Dynamical Symmetries For Odd-Odd Nuclei Near Proton Drip Line***

Work on the structure of nuclei near proton drip line was initiated last year and in order to study first the structure of heavy  $N=Z$  odd-odd nuclei, this year 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  $(ST)=(10) \oplus (01)$  are classified (last year studied are the symmetry schemes of the model with only  $T=1$  bosons which is adequate for heavy even-even nuclei). The spectrum generating algebra (SGA) for the model is  $U(36)$  and for this SGA it is shown that at the primary level of the group-subgroup lattice there are four limits: (i)  $U(6) \otimes U(6)$ ; (ii)  $U(18) \oplus U(18)$ ; (iii)  $U(6) \oplus U(30)$ ; (iv)  $O(36)$ . A group chain in  $O(36)$  limit (the  $O(36)$  eigenstates have  $\alpha$ -particle type correlations) is developed in detail for studying two problems of current interest. Firstly, with a simple mixing hamiltonian, it is shown that this group chain generates, for heavy  $N=Z$  nuclei, even-even to odd-odd staggering in the number of  $T=0$  pairs in the ground states for moderate difference in the basic  $T=0$  and  $T=1$  s-boson pair energies; the staggering disappears when the energy difference is large. Secondly, properties of the observed ground  $T=1$  and excited  $T=0$  bands in  $^{74}\text{Rb}$ , which is the heaviest known  $N=Z$  nucleus with any spectroscopic detail, are described by the  $O(36)$  chain; the  $T=0$  band is predicted to be due to the spin  $S=1$  alignment of a np pair.

(V.K.B. Kota)

### ***Complexity and Chaos in Nuclear Shell Model Transition Strength Distributions***

It is known from the developments in statistical spectroscopy (SS) that embedded Gaussian ensembles with k-body interactions (EGOE(k)) are more appropriate for interacting many-body systems such as atomic nuclei; in the last few years with the developments in the subject of *quantum chaos*, there is new interest in developing further and applying SS and EGOE to atoms, molecules and solids, mesoscopic systems etc. In a first study, the bivariate Gaussian form for smoothed strength densities



given by statistical spectroscopy (equivalently by EGOE) is used to derive formulas for information entropy (S) and number of principal components (NPC), which are measures of complexity and chaos, in transition strength distributions. They describe, in terms of the bivariate correlation coefficient ( $\zeta$ ) the shell model results and reduce to GOE results for  $\zeta = 0$ ; GOE gives  $N/3$  for NPC and  $\ln(0.48N)$  for S where N is matrix dimension. The shell model results show strong secular (energy) variation (PRL scientists performed shell model calculations in 5 and 6 particle (ds) shell spaces) and they are well reproduced by the EGOE (SS) formulas. This work was done in collaboration with Dr. R. Sahu of Berhampur University.

(V.K.B. Kota)

## PLASMA PHYSICS

### *Temperature Anisotropy and Instability in Accretion Disks*

Physical understanding of accretion disks is undergoing major changes in the recent time. Firstly due to the realization that origin of the turbulence in a disk can be magnetic in nature and which can answer some of the outstanding puzzles like: the origin of anomalous viscosity and the angular momentum transfer in accretion disk. And secondly due to the advent of advection dominated accretion flow (ADAF) models which has replaced the earlier standard disk (SD) models. In ADAF models, the accreting gas comprise of plasma which has electrons at significantly lower temperature than the ions and the accretion flow is rather quasi-spherical unlike SD models. However, the work which ascribe accretion disk turbulence to the instability of a sheared flow in the presence of a weak magnetic field considers the accretion disk as geometrically thin and having Keplerian flow velocity. But these assumptions are not valid for ADAFs. It is likely that the instability can heat the plasma in an anisotropic way temperature of the plasma may be different in parallel and perpendicular direction of the instability generated magnetic field. Keeping above in mind we have studied a systematic study of how the magnetic instability get affected by ADAFs conditions and how temperature anisotropy can modify it. We find that temperature anisot-

ropy may cause the fire-hose instability to develop in the plasma in late stage of the sheared flow instability. This work was done in collaboration with Prof. P.K. Kaw.

(Jitesh Bhatt)

### *Neutral Dynamics and Electromagnetic Modes in Partially Ionized Plasma*

Electromagnetic modes in a partially ionized, inhomogeneous and magnetized plasma are investigated by taking into account of the effects of neutral dynamics. Using the set of Maxwell's equations and basic fluid equations that describe neutrals and plasmas, the existence of new type of plasma instabilities in the low frequency domain both for strong and weak plasma neutral coupling cases has been demonstrated. It is also shown that the results obtained earlier in this field of research can easily be retrieved from our most general dispersion relation. The modified version of the pre-existing modes as well as the generation of new modes due to neutral dynamics are highlighted. It has also been pointed out the relevance of these modes in several reported laboratory and space phenomena and hence it demonstrates the significance of neutral dynamics. This work is done in collaboration with A.A. Shaikh, C.U. Shah Science College, Ahmedabad.

(A.C. Das)

### *Field Aligned Current and Particle Acceleration Near the Io-Plasma Torus*

A model of field aligned current system in the Jovian magnetosphere particularly near the Io plasma Torus is developed on the basis of shear plasma flow around Io with the addition of mass injection from the atmosphere of Io into this flow. It is shown that the mass momentum transfer from Io can produce large enough current along the magnetic field which can generate an ion-cyclotron wave. A nonlinear mechanism which generates kinetic Alfvén wave parametrically by ion cyclotron wave in a closed system of ion-cyclotron and kinetic Alfvén wave has been re-investigated. It is shown that the kinetic Alfvén wave generated by this mechanism can produce an electric field large enough to accelerate particles to a

few tens of kiloelectron volts within a fraction of Alfvén time scale. Thus the model is capable of generating both electrostatic and electromagnetic wave associated with the beam of energetic electrons in the Jovian auroral region. This energetic beam of electron will also be able to produce hiss observed in the Jovian magnetosphere associated with Io-Plasma Torus. This work is done in collaboration with W.-H. Ip, Max Planck Institut für Aeronomie, Germany.

(A.C. Das)

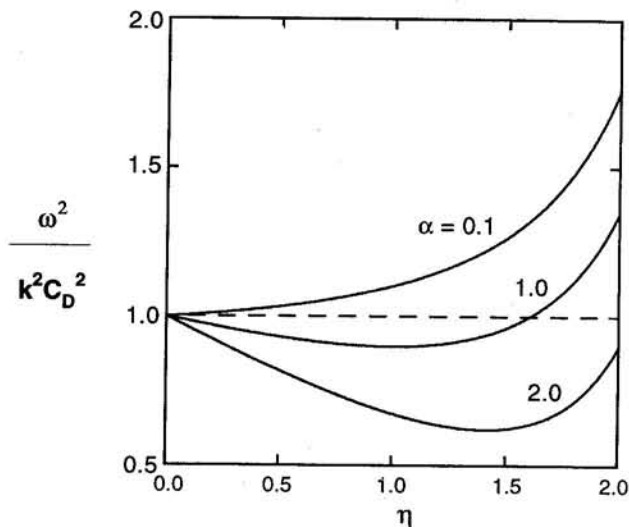
### **Dust-Acoustic Waves in Non-Ideal Dusty Plasmas**

Dust-acoustic wave propagation in a non-ideal classical dusty plasma consisting of electrons, ions and dust grains is investigated by incorporating the van der Waals equation of state for the dust component. For linear waves, it is found from the normal mode dispersion relation that the volume reduction coefficient enhances the phase speed of the dust-acoustic waves while the molecular cohesive forces lead to a decrease in the phase speed. The relative magnitudes of the two contributions depend on the specific parameter regimes characterizing the non-ideal nature of the dust component. In the high-temperature limit, there is a net increase in the dust-acoustic phase speed while near the critical point the phase speed is reduced when compared with that for the ideal gas case (**Fig. 2.2**). For large amplitudes, we discuss the existence of dust-acoustic solitons by deriving the exact Sagdeev potential. While super-sonic solitons are found to be admissible both in the sub- as well as super-critical parameter regimes, sub-sonic propagation near the dust-acoustic speed is possible only for the super-critical case. For small but finite amplitudes, explicit analytical solutions have been obtained.

(N.N. Rao)

### **Linear and Nonlinear Dust-Acoustic Waves in Inhomogeneous Dusty Plasmas**

The propagation of dust-acoustic waves in inhomogeneous dusty plasmas consisting of electrons, ions and charged dust particles is investigated. It is shown that the amplitude of the dust-acoustic waves is affected by the presence of the dust density inhomogeneity.



*Fig. 2.2 Variation of the normalized phase speed ( $\omega / kC_D$ ) of the linear Dust-Acoustic Wave (DAW) in a dusty plasma with respect to the non-ideal parameters  $\eta = n_{d0}/n_c$  and  $\alpha = T_e/T_d$ . The dotted line corresponds to the ideal dust fluid case, and corresponds to the high-temperature limit ( $\alpha \rightarrow 0$ ) for a dilute gas ( $\eta \rightarrow 0$ )*

Amplitudes of the linear and nonlinear dust-acoustic waves decrease (increase) as the waves propagate in the direction of increasing (decreasing) density. The wave amplitude is inversely proportional to the square root of the dust particle's density for the linear dust-acoustic waves. In the nonlinear case, to the lowest order and for the cold dust species, the wave amplitude is found to be directly proportional to  $n_{d0}^{-1/4}$ . Various special cases are explicitly considered, and comparison with the corresponding results for the usual two-component electron-ion plasmas is also carried out.

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

### **Kelvin-Helmholtz Instability in the Presence of Dust Charge Fluctuations**

Kelvin-Helmholtz instability is examined by considering dust charge fluctuations in a dusty plasma. Electrons and ions are considered to be in Boltzmann equilibria and the dust grains to follow the fluid equations with full adiabatic equation of state. The instability is found to grow for limiting wave numbers for a particular value of shear velocity. The effect of adiabatic dust plasma pressure is to enhance the growth rate of the instability. The effect of charge variation is not seen on the growing mode of the

instability. However, dust charge variation gives rise to a purely damped mode in addition to growing mode. This work was carried out in collaboration with R. Bharuthram.

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

### ***Integrability of Coupled Generalized Schrödinger-Boussinesq System***

It is well known that the nonlinear coupling of an amplitude modulated high-frequency wave to a suitable low-frequency wave via the ponderomotive force leads, in general, to the Schrödinger-Boussinesq system of time-dependent governing equations. Depending on the nature of the coupled waves, the equations have different coefficients, and hence it is important to analyze the integrability as well as the exact analytic solutions of these equations with arbitrary coefficients. Keeping this in mind, we have carried out the Painlevé analysis of generalized Schrödinger-Boussinesq system. We identify two branches of leading singularities for the generic system by using the Painlevé formalism for PDEs. The coupled system is shown to be completely integrable in one of the branches, for which case the associated Backlund transformation is explicitly obtained. Relevance of the results for coupled nonlinear wave propagation in magnetized plasmas is pointed out. Analytic solutions for the stationary coupled equations are being worked out. This work was carried out in collaboration with A. Roy Chowdhury and B. Dasgupta.

(N.N. Rao)

### ***Extended Henon-Heiles Hamiltonian for Coupled Nonlinear Waves***

We propose an extension of the Henon-Heiles Hamiltonian to include higher order nonlinear as well as coupling terms which are relevant for coupled nonlinear wave propagations in plasmas. It is shown that the resulting Hamiltonian, in its generic form, is integrable for two regimes in the parameter space. The second integral of motion in each case is explicitly obtained. Work to explicitly obtain exact localized solutions of the relevant governing equations for the coupled waves corresponding to the two integrable cases of the generic Hamiltonian is in progress.

(N.N. Rao)

### ***Nonlinear Langmuir Waves in Two-Electron-Temperature Plasmas***

We investigate the propagation of nonlinear Langmuir waves in a bi-Maxwellian plasma consisting of two-electron-species in the critical parameter regime ( $\Delta=3$ ). It is shown that there exists a new class of Langmuir envelopes which have qualitatively different structure from the solutions reported earlier. In particular, the Langmuir field envelope has two nodes, and accordingly the field intensity has a triple-hump structure. The low-frequency density perturbation which traps the Langmuir field has the usual single-dip structure. The coupled fields co-propagate with supersonic speeds but are accompanied by density rarefactions.

(N.N. Rao)

### ***Anomalous Particle Pinch in Tokamaks***

An anomalous particle pinch in tokamaks has been known to exist since the T-3 tokamak. However, it is now known to occur in almost all tokamaks. But there is no satisfactory explanation reported for it so far. A theory is given to understand this pinch based on an idea given by the author earlier. The induction electric field polarizes the trapped particles, producing a polarization charge density in the  $(r, \theta)$  plane. The polarization electric field so produced crossed with the toroidal magnetic field leads to an  $E \times B$  drift of all the plasma particles, which has been shown to have a  $\theta$ -averaged radially inward component  $\langle V_r \rangle = (8/9)\epsilon^{1/2} (1 - \epsilon^{1/2})^{-1} V_{\text{Ware}}$ , where  $V_{\text{Ware}}$  is the Ware pinch velocity  $(-cE_\theta/B_\theta)$ , and  $\epsilon$  is the inverse aspect ratio: For most tokamaks  $\langle V_r \rangle$  is found to be of the order of the observed inward drift  $10\text{ms}^{-1}$ .

(R.K. Varma)

### ***Instabilities of Inhomogeneous Plasmas Streaming Relative to Inhomogeneous Dust Distributions***

Streaming instabilities are studied for an inhomogeneous plasma streaming through an inhomogeneous distribution of dust particles. Such situations are characteristic of the neighbourhood of stars where stellar plasma wind ploughs through dust shells



around stars. This should result in the acceleration of dust particles at the expense of the plasma momentum, which may throw light on certain dynamical features of the dust cloud vis-a-vis the plasma dynamical features. Streaming instabilities are a first step towards such a study. Various cases of the relative magnitudes of the plasma and dust velocities are analysed, and the role of inhomogeneities is highlighted. It is found, for example, that the case which is stable in the absence of inhomogeneity, namely, that when  $v^2 > (1/4) C^2$ , where  $v$  is the relative plasma-dust drift velocity, and  $C$  is the ion-acoustic speed, is rendered unstable by the inhomogeneity. In the opposite case, on the other hand, namely when  $v^2 < (1/4) C^2$ , the inhomogeneity adds only a small correction term to the already unstable case without the inhomogeneity.

(R.K.Varma)

### ***The Double-Slit Interference Phenomena as a Topological Effect***

The double slit interference has served as a highly illustrative paradigm for the quantum wave phenomena for material particles. But in classical dynamics, the double slit presents a peculiar problem: First of all, even across a single slit, the motion is not well defined because of the singular nature of the slit potential, specially at the "edges". It presents a scattering problem; there is no single well defined trajectory through the slit, but a whole multitude of possible ones. The action at a point  $P$  along one such possible paths can, however, be calculated across the slit. But when two slits are present, the action becomes a double valued function of position corresponding to the two possible paths through the two slits. By attaching a  $U(1)$  fibre bundle, the multiply-connected space of the double slit may now be made singly-connected. One can then demand that the action at any given point across the double slit be single-valued. This "physical principle" is shown to yield the discrete angular directions which correspond to the maxima of the interference fringes. The  $\ast$  is introduced here as a momentum conjugate to the  $U(1)$  fibre bundle.

(R.K. Varma)

## **NONLINEAR DYNAMICS AND COMPUTATIONAL PHYSICS**

### ***Parameter Estimation***

A technique is introduced for estimating unknown parameter/s when only one time series is available as an output from a nonlinear system. It employs linear feedback for synchronising system variables whereas parameter estimation is achieved by adaptive control. The method is shown to work even when the unknown parameter appears in the evolution equations of the variables other than the one for which the time series is given. Illustrations are presented for Lorenz and Rossler flows. This work was done in collaboration with A. Maybhathe.

(R.E. Amritkar)

### ***Percolation of Finite-sized Objects***

We study the percolation of finite-sized objects on two- and three-dimensional lattices. Our motivation stems, on one hand from some recent interesting experimental results on transport properties of impurity-doped oxide perovskites, and on the other hand from the theoretical appeal that this problem presents. Our system exhibits a well-defined percolation threshold. We estimate the size of magnetic polarons, believed to be the carriers of the above mentioned transport. We have also obtained two critical exponents for our model, which characterize its universality class. This work was done in collaboration with M. Roy.

(R.E. Amritkar)

### ***Quantum Statistical Mechanics from Quantum Chaos and Random Matrix Theories***

We have been studying the connections between quantum statistical mechanics and quantum chaos. In particular the question of whether quantum chaos can give rise to anything like the micro-canonical ensemble in low dimensional quantum chaotic systems. Using various quantum chaotic maps we found that this is the case and that the average expectation values of typical operators is statistically independent of the initial state. Further, using Random Matrix models we are able to derive all the

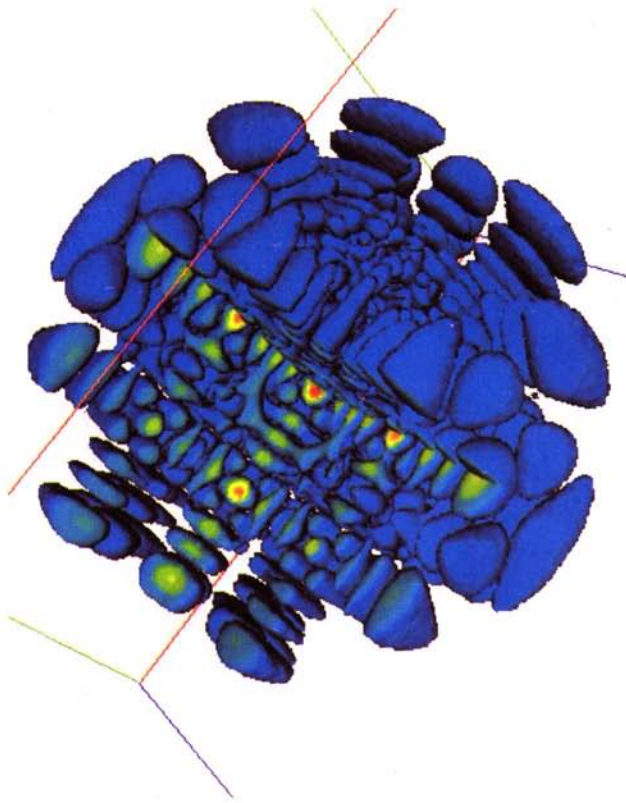


Fig. 2.3 Ongoing studies on chaotic quantum systems involve investigations of structures in wave functions of three dimension systems. Shown here is an isosurface for a three dimensional quartic oscillator system. Localized wave function is shown within the excavated portion.

principle dependencies of the relaxation to the equilibrium, as well as the scaling with the size of the system, or the effective Planck constant. This follows up on our earlier published work on relaxation fluctuations in quantum chaos.

(A. Lakshminarayan)

### ***Dynamical Tunnelling in Quantum Chaotic Anharmonic Oscillators***

We have shown that in smooth two dimensional coupled anharmonic oscillator systems a series of eigenfunctions are scarred by the simplest straight line periodic orbit. We are studying the tunnelling splitting of these states among the different symmetry related classes. The presence of the splittings even in regimes of deep classical chaos is novel and interesting. We are studying

the characteristics of these splittings as a function of the stability of the scarring orbits.

(V.B. Sheorey, M. S. Santhanam and A. Lakshminarayan)

### ***Incommensurability in a Generalized Standard Map: Quantum and Classical Aspects***

A particle in a potential well subjected to time periodic electromagnetic pulses provides a generalized model of the important standard map of non-linear dynamics. We have found that if the well width and the pulse wavelength are incommensurate novel new effects are found. Even for low values of the field intensity this can lead to a destruction of rotationally invariant circles thereby inducing much more transport. A range of diffusive behaviours have been found from the sub-diffusive through the normal to the Levy type in these models whose quantum versions also are being studied. Recent experimental realizations of the quantum standard map make this work of great potential interest.

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

### ***GCM Simulation of Surface Winds in the Tropics during 1979-1988***

In a coupled ocean-atmosphere system, atmosphere component forces the ocean component through surface winds. The coupling between two components largely depends on the mean climate of the individual component. So an AGCM, which simulate mean climate and low frequency variability well, will be an ideal choice for atmospheric component of a coupled GCM. In this work the GCM's capability to simulate the mean climate in the tropical Pacific and the low frequency variability associated with ENSO is examined by analyzing surface winds from GCM's 10 year integration forced by observed SSTs during 1979-1988. The NMC/NCAR reanalysis 10m winds is used for comparing model simulated surface winds.

The simulated southern oscillation index(SOI) from 1979 to 1988 shows that the AGCM has simulated observed southern oscillation(SO) in response to the globally varying observed SSTs. The phase of two El



Nino events(1982-1983 and 1987) during 1979 to 1988 matches well with observations with slightly weak amplitude. The model simulated annual mean zonal and meridional winds has remarkable resemblance with the observations. The annual cycle of zonal and meridional winds matches reasonably well with observations but the semi-annual cycle of zonal and meridional winds is poorly simulated. The comparison of mean January and July winds is also done. To assess the large scale low frequency variability of the model simulated surface winds, EOFs(empirical orthogonal functions) of surface wind anomalies are constructed. The EOFs and PCs(principal components) of model simulated surface winds have many similar patterns with observations. Especially, AGCM has captured the observed eastward propagation of westerly wind anomalies from western Pacific to eastern Pacific during 1982-83 El Nino event. This work was done in collaboration with Dr. V. Satyan.

(Biju Thomas and S. V. Kasture )

### ***Study of Dynamics of Inflation in India using Neural Network Approach***

The dynamics of inflation in India is studied using artificial neural network (ANN) method. The basic idea is to apply this new non-parametric modelling technique to examine the dynamics. The advantage of ANN are that it makes weak assumptions to model the system. Further, it can easily incorporate nonlinearities in the modelling of the dynamics, and the model is generated from the data. With this view in mind we considered the average monthly values from April 1975 to March 1996 of the following macroeconomic variables viz. broad money supply (M3), effective exchange rate (REER), foods stocks (FOOD), index of industrial production (IIP), whole sale price index (WPI) and consumer price index (CPI). In order to understand the nature of the dynamic system we carried out pre-analysis of each of the above time series. The objective is to find out if the time series reflects behaviour which is i) deterministic or stochastic, ii) linear or nonlinear and iii) regular or chaotic. The pre-analysis also helps in partially determining the architecture of the neural network. Following the pre-analysis, univariate ANN models were constructed for each of the series. Excellent fits to

the data were obtained. Out of sample forecasts for the period April 1996 to March 1997 were also made. We also carried out multivariate studies using ANN. There were three parts to the multivariate studies.

1. To establish nonlinear relations between the macroeconomic variables. We could get excellent fit to these relationships, especially for the variables M3, WPI, and REER with mean error below 2%.

2. To construct multivariate ANN models which fit the data and make out of sample predictions for the period April 1996 to March 1997. It was found that the multivariate ANN models could, in general, yield better short term predictions than those obtained by conventional methods.

3. To give impulses to M3 and REER and study the impact of the impulses on WPI. Such studies have important implications for policy and can not be carried out using conventional approach.

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

### ***Characterization, Simulation and Modelling of Electroencephalograph Signal***

Electroencephalograph (EEG) data for normal individuals with eyes closed and under stimuli is analysed. The stimuli consisted of photo, audio, motor and mental activity. We find that the dynamics of EEG signal is deterministic and chaotic but it is not a low dimensional chaotic system. The evoked responses lead to a redistribution of strengths relative to eyes closed data. Basically strength in  $\alpha$  waves decreases whereas that in  $\beta$  wave increases. With mathematical and motor activity strength in  $\delta$  and  $\theta$  waves also increases. We also carried out simulations separately and in combination for  $\delta$ ,  $\theta$ ,  $\alpha$  and  $\beta$  waves to understand the data. From the simulation results it appears that the characteristics of EEG data are consequences of filtering the data with a relatively small range of frequency (0.5-32 Hz). In view of this, we believe that calculation of known nonlinear measures is not likely to be very useful for studying the dynamics of EEG data. We have also successfully modelled the EEG time series using the concept of state space reconstruction in the



framework of artificial neural network. It gives us confidence that one would be able to understand in a more basic way how the collectivity in EEG signal arises.

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

**Pattern Recognition Tool Box**

A general purpose Pattern Recognition Tool Box package is developed in Visual C++ to work with Win95 (Fig.2.4). The package is designed for 2-D graphics images. The front-end of system consists of a vector

graphics editor with features like Draw different types of Shapes, Font select, Zoom, Drag entity, Undo etc. The input image is segmented and vector quantized using a configurable feed forward type neural network to extract features. The feature set is further applied to another configurable neural network to classify the image and recognise. The networks are initially trained with large number of similar image sets using back propagation algorithm.

(H.S. Mazumdar)

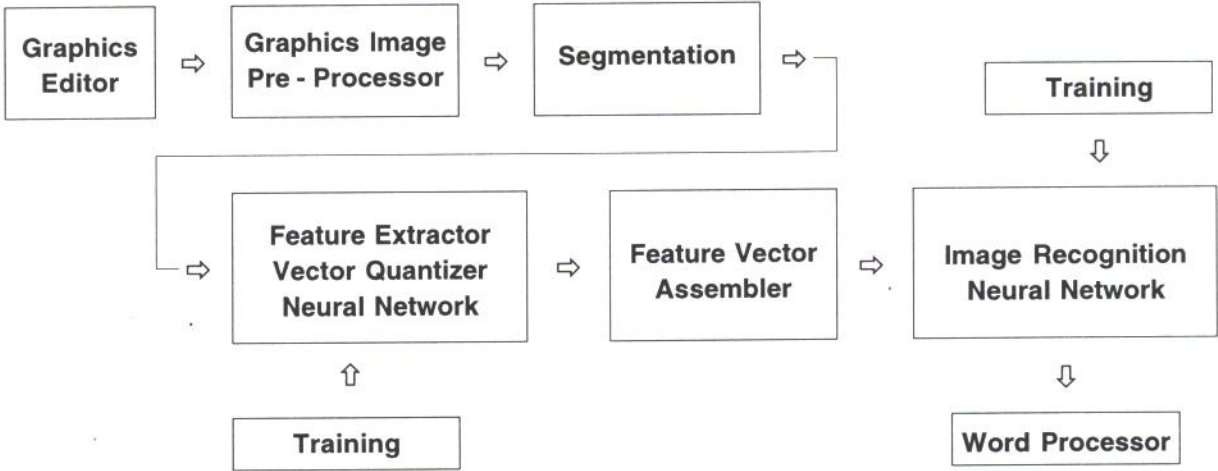


Fig.2.4 Block diagram of hand written character recognition system

The research interest of this division covers a range of topics dealing with the quantum and nonlinear aspects of light and light-matter interaction such as optical manipulation of atoms, control of spontaneous emission, giant nonlinear optical effects, wave packet dynamics and generation of nonclassical light. Some of the research activities of the past year are as follows.

## ***Cloning, Dragging, and Parametric Amplification of Solitons in a Coherently Driven, Non-absorbing System***

The development of new techniques for pulse shaping and control is central to generating tailored pulses for communications, study of ultrafast processes, and preparation of atoms and molecules in desired quantum states.

Driven atom dynamics continue to receive tremendous attention, and our work represents a qualitatively different way of exploiting these dynamics. We focus on solitons in three-level atoms. Our principal results are that in a non-absorbing, resonant  $\Lambda$  system (i) a weak field of *arbitrary* profile at the Stokes transition is parametrically amplified into the replica of a soliton at the pump transition (*cloning*), (ii) the degree of overlap between the input pump and Stokes pulses permits a control over the temporal location of the Stokes soliton (*dragging*), as well as its amplitude and phase, and (iii) the cloned soliton, which has a different frequency from the pump soliton, travels at the speed of light,  $c$ , and hence is a steady state pulse. This is an unusual property of the cloned pulses generated in a three-level system since solitons generated in two-level atoms always propagate with a speed less than  $c$ , and so depend on both local space and time coordinates. This work was done in collaboration with G. Vemuri and K. V. Vasavada of Indiana University-Purdue University, Indianapolis.

(G. S. Agarwal)

## ***A Model for Mode Hopping in Optical Parametric Oscillators***

An optical parametric oscillator (OPO) operating as a doubly resonant oscillator (DRO) can be an ideal source of tunable radiation except that there are large frequency

instabilities due to the phenomenon of mode hopping. Although there has been many qualitative approaches, a quantitative treatment of this phenomenon has been long overdue.

This we provide by developing a model where the pump can feed two pairs of signal-idler modes. We obtain the various steady states of interest, namely when only the first pair oscillates with the other pair having null amplitudes and vice versa. A stability analysis reveals that there can be exchange of stability between the oscillating and the zero amplitude pairs. We derive conditions for the exchange of stability in terms of cavity parameters, which can change because of changes in the cavity length or fluctuations in the phase of the pump. We demonstrate the exchange of stability from numerical solutions of coupled nonlinear equations for five complex modes (i.e., the pump and the two signal idler pairs). For a specific choice of parameters we also demonstrate the excitation of both the pairs. This work was done in collaboration with S. Dutta Gupta of University of Hyderabad.

(G. S. Agarwal)

## ***Atomic Schrödinger Cat States***

The concept of superposition of macroscopically distinct quantum states, i.e., the Schrödinger cat states plays an important role in understanding the conceptual foundations of quantum mechanics. The methods for generation of such superposition states are, therefore, of fundamental interest. Much attention has been paid in the generation and study of the cat states of the *electromagnetic field*. The macroscopic states in that case are the field coherent states with large number of photons. Such states can generate cat states via a non-linear interaction such as when the field propagates through a Kerr medium in which case the non-linearity corresponds to a Hamiltonian which is quadratic in the field number operator.

We show that cat like states can also be generated for a system of spins or equivalently a system of two-level atoms. The macroscopic states in this case are the spin or atomic coherent states (ACS). We demonstrate that a superposition of such states can produce *atomic* cat states by an effective interaction which is non-linear in the



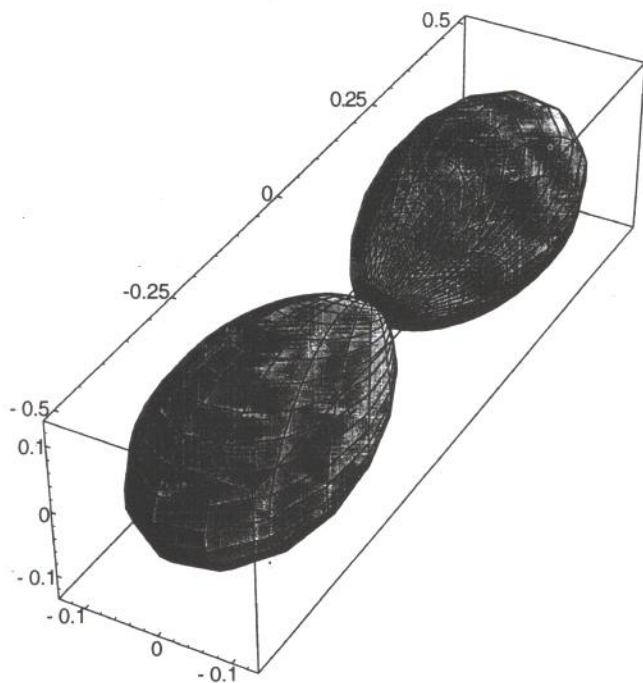


Fig. 3.1 The (quasi) probability distribution in phase space for an atomic CAT state

operator for atomic population inversion. This non-linear interaction is shown to be *realizable* in the experiments on two-level atoms in a low-Q cavity highly detuned from the atomic transition frequency, the light shift due to the vacuum field inducing the required non-linear interaction.

We study in detail the quasi-distributions for these states and demonstrate how the cat states can lead to interesting interferences over the surface of a sphere (Fig. 3.1). This work was done in collaboration with R. R. Puri of BARC, Mumbai.

(G. S. Agarwal and R. P. Singh)

### **State Reconstruction for a Collection of Two-Level Systems**

There have been a number of proposals for the reconstruction of the density matrix for a single mode of the radiation field and the reconstructions of several states of the radiation field have been reported. Some of the proposals have been generalized to two modes of the radiation field. However, almost all the literature has been exclusively devoted to the reconstruction of the state of

the harmonic oscillator systems, which include radiation field, the motional state of the trapped atom and ion, and the vibrational state of the molecular wave packet in harmonic and anharmonic potentials. Very little has been done on other systems.

Here we report reconstruction of the state of a spin system with arbitrary spin value. This study is relevant to a number of systems in quantum optics and in other fields, for example, a collection of  $N$  two-level atoms can be modeled in terms of a spin system with spin value  $N/2$ . The polarization of light can also be described by spin, e.g., the well-known Stokes parameters can be written in terms of the expectation values of spin operators. The fluctuations in spin operators will lead to fluctuations in Stokes parameters. Such fluctuations have in fact been used to introduce the concept of polarization squeezing. One thus needs to have a reconstruction procedure for a spin system with an arbitrary spin value  $S$ .

We have proposed such a scheme for reconstructing the quantum state of a system of atoms or spins. The  $Q$  distribution is derived from the measured population in the ground state of a system that has interacted with an external field. Using multipole operators the  $Q$  function is inverted to derive the density matrix. Our method in combination with the known methods for the radiation field will enable us to reconstruct the complete density matrix of the interacting atom-field system.

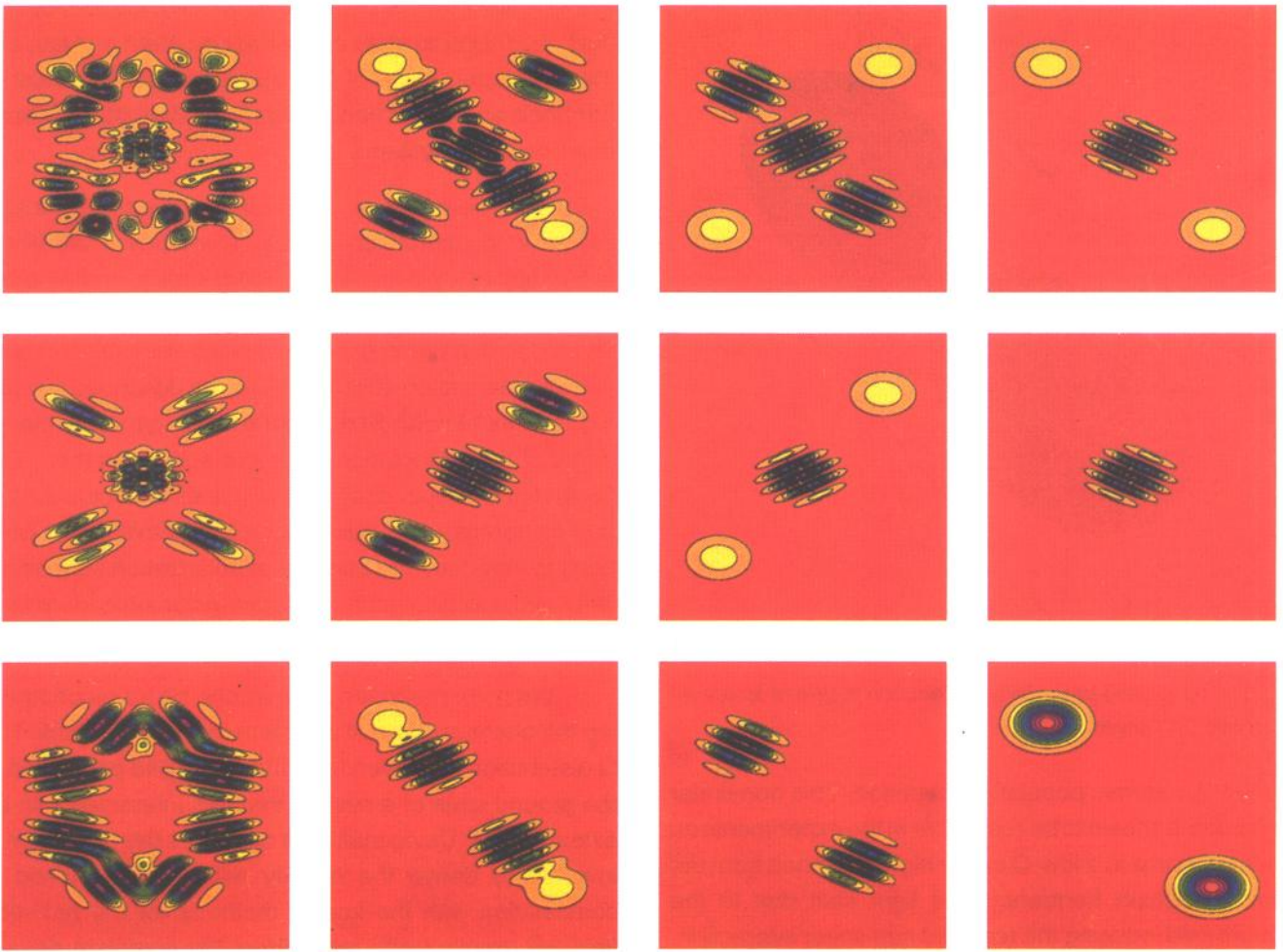
(G. S. Agarwal)

### **Fractional Revivals and Cat-like States in Systems with Two Time Scales**

Two striking features in the nonlinear evolution of certain quantum systems are the formation of coherent structures such as Schrödinger cats and the occurrence of full, fractional or super revivals.

After explicit calculations for many systems it is now apparent that these phenomena are quite generic and are, in fact, closely connected to the energy spectrum of the underlying Hamiltonian and the periodicity of the time evolution operator. In most cases the nonlinear dynamics can be understood by the first anharmonic contribution to the energy spectrum.





*Fig. 3.2 Contour plots of the probability densities for a two-mode coherent state (top row) and for its even (middle row) and odd (bottom row) constituents depicting fractional revivals under a generic Hamiltonian. Each column refers to a different instant of time.*

The literature deals mostly with systems whose energy spectrum depends on a *single* quantum number. In reality, many systems exist whose energy levels depend non-linearly on at least two quantum numbers. It is thus essential that a general theory for these systems be developed to uncover the generic features of their nonlinear quantum evolution.

With this objective in mind we study the wave packet dynamics of these systems under the action of a generic Hamiltonian that contains the leading anharmonic terms in the energy spectrum. We explain the complex revival structure of these systems and their constituent 'odd' and

'even' states (i) by deriving explicit analytical results and (ii) by studying the evolution of auto-correlation functions, phase distributions and probability densities (**Fig. 3.2**). We specifically examine the new effects that arise from the existence of two time scales which themselves are determined from the dependence of the energy spectrum on two quantum numbers. We show that the ratio of these time scales as well as the symmetry of the initial wave packet are crucial factors in determining the revival characteristics of the system.

(G. S. Agarwal and J. Banerji )

## ***Super-Revivals in the Quantum Dynamics of a Particle Confined in a Finite Square Well Potential***

An ideal model system to illustrate the fractional revival phenomenon is the infinite square well potential since simple analytical forms of the eigenvalues and the eigenfunctions allow for an easy analysis of the time evolution of any initial state. This system has been recently studied in some detail in the context of fractional revivals. An experimental realization of the predictions of the fractional revival phenomenon in the infinite well is most likely to be in semiconductor quantum well systems. In reality, however, it is rather impossible to find a physical system that creates a truly infinite confining potential. It becomes crucial, therefore, to look at the problem of revivals in more realistic physical systems which are closer to finite well potentials rather than infinite potentials.

We have looked at the revival features in the wave packet dynamics of a particle confined in a finite square well potential. We show that the revival pattern will be different from what one gets for an infinite square well potential because of tunneling effects. In particular, a whole range of revivals and super-revivals will be allowed and the revival times in general will depend on the depth of the finite square well. These effects could be realized experimentally and tested in semiconductor quantum well structures.

(A. Venugopalan and G. S. Agarwal)

## ***Collective Excitations of a Binary Bose Condensate in an Axially Symmetric Trap***

Ever since their experimental realization in trapped alkali atom gases, Bose condensates have attracted a great deal of interest. The Bose condensate is a weakly interacting quantum many-body system. As such, one of its important features is its collective excitation.

In a recent experiment, a binary Bose condensate was formed in which the two components were in different hyperfine states of  $^{87}\text{Rb}$  atoms. A key parameter in the collective excitation of a binary Bose condensate is the coupling  $V_{12}$  between atoms of different components. For  $V_{12}=0$ , the mode spectrum of each component will be that

of an isolated condensate, whereas for non-vanishing  $V_{12}$ , these bare frequencies will be dressed by the interaction.

Using the Thomas-Fermi approximation we derive the spectrum of collective excitations of a pure binary-phase condensate in an axially symmetric trap and show that the excitation frequencies are related to those of a single-component condensate by a scaling. Furthermore, since experiments to-date have been performed with traps of axial symmetry for which the complete spectrum of a single condensate is known, this scaling is very important as it allows us to obtain the complete spectrum for a pure binary-phase condensate also. Finally, we identify and find conditions for the occurrence of several accidental degeneracies in the spectrum due solely to the interaction between the two components of the binary condensate. These accidental degeneracies will strongly enhance nonlinear effects in the evolution of the binary condensate when it is excited by a suitable driving force.

(J. Banerji and G. S. Agarwal)

## ***Squeezing in Down Conversion in Quasi-Phase Matched Medium***

Squeezed states of light are very important quantum states of the electromagnetic field. They have been studied extensively both from the point of view of fundamental physics as also for their applications in high precision interferometry and improved spectroscopy. Hence, there is interest in the generation of squeezed states which is conventionally done in media with nonvanishing second order nonlinear susceptibility. Quasi Phase Matched (QPM) materials have become very important in this context, because the efficiency of frequency conversion in these materials is much higher than in other materials with nonvanishing second order susceptibility. The question therefore arises if one can enhance squeezing using such media.

We consider the generation of squeezed light in the process of down conversion in a quasi-phase matched (periodically poled) nonlinear medium. It is found that the amount of squeezing is quite high for well phase matched interactions and with high powers. Analytical as well as

numerical calculations show how squeezing in the down-converted mode depends on the phase mismatch parameter, the order of phase matching and the input pump power.

(V. S. Chickarmane and G. S. Agarwal)

### ***Coherent Population Trapping in the Presence of Inherent Interference Effects***

Coherent population trapping (CPT) is a very important phenomena for laser cooling, laser spectroscopy and quantum optics in general. The most favored configuration to study such related phenomena is a three level  $\Lambda$  system with well separated ground levels. But in the case of a  $\Lambda$  system with closely spaced ground levels, inherent interference due to vacuum field can give rise to spontaneously generated coherence (SGC). In particular, the response of a  $\Lambda$  system exhibits significant changes due to SGC.

We have shown the possibility of both CPT and electromagnetically induced transparency (EIT) in the presence of SGC. We also look at the dynamics under CPT condition, and predict the lengthening of time scale due to SGC. We demonstrate these numerical results through a simple analytical picture, and also explain physically the earlier results. Further, we have reported the possibility of *phase sensitive* response, acquired by the medium, due to SGC.

(Sunish Menon and G. S. Agarwal)

### ***Giant Nonlinear Optical Effects***

One of the goals in nonlinear optics has been to improve the efficiency of the generation. Several proposals have been made. In many of the proposals the atomic coherence plays an important role. The atomic coherence is maximized in a coherent population trapping (CPT) state. An ensemble of Pb atoms prepared in this maximum coherence state was utilized by Harris and co-workers for efficient conversion of blue light to ultraviolet. They obtained efficiency of around 40% in the generated signal.

We develop a non-perturbative approach to study the generation of nonlinear signals in a coherently pre-

pared medium. Specifically, we study the nonlinear mixing process  $\omega_1 - \omega_2 + (\omega_2 + \Omega)$  in a system prepared in a CPT state. We calculate enhancement factors of the order of 100 in the generated signal, under a variety of conditions. Moreover, our non-perturbative analysis also enables us to find out if pulse matching can occur in a thick medium at high probe powers. We find the remarkable result that even at high probe intensities, pulse matching does take place.

From our analysis, it is clear that by choosing various other atomic schemes one could enhance other nonlinear mixing processes using the coherence of the population trapped state.

(W. Harshawardhan and G. S. Agarwal)

### ***Laser Field Induced Quantum Beats in Photon Correlations***

It is well known that a V-system can exhibit quantum beats in fluorescence if initially the system is prepared such that there is coherence between excited states. It is also known that quantum beats are sensitive to whether one considers a system with upper state coherence or a system with lower state coherence. For example, a  $\Lambda$  system with initial coherence between two lower states does not lead to quantum beats. One could thus inquire the possibility of beats in a four level system with two intermediate states such that the upper part of this system is like a  $\Lambda$  system and the lower part like a V-system.

Clearly quantum beats will occur at the frequency separation between the intermediate states if the process of spontaneous emission can *create coherence* between these states. However, calculations show that this will not happen for most atomic systems and hence one has to explore appropriate ways to induce coherence.

We show that this can be achieved by manipulating energy levels using laser fields. The laser fields mix the energy levels via ac-Stark splitting and make the dipole matrix elements dependent on the strength and frequency of the laser leading to the recovery of quantum beats.

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



### ***Enhancement of Lasing near a Reflecting Substrate***

We want to study lasing threshold or enhancement of lasing in the distributed feedback (DFB) structure created in a dye monolayer placed before a mirror. For this system fluorescence lifetime has been observed to be a function of distance from the mirror, so we can select an optimum distance, by depositing monolayers of inert spacers in between, at which fluorescence lifetime is minimum or fluorescence is maximum to minimise the lasing threshold.

We have successfully deposited monolayers of a long chain hydrocarbon with Rhodamine B as a chromophore on glass and mirror substrates after optimising surface pressure and lifting speed in a Langmuir-Blodgett (LB) trough. Absorption spectra of the sample in a dilute solution as well as in the layered form on a glass substrate have been recorded. Structural similarity of the spectra in both the forms shows that there is no clustering of sample in the layer and these are monolayers only. However, for the monolayer sample substantial absorption takes place around 250nm only, necessitating a coherent UV source for excitation and DFB creation. The emission spectra of the monolayers on the glass substrate have also been recorded with a peak around 605nm. This work was carried out with Prof. T.N. Misra, Department of Spectroscopy, IACS, Calcutta.

(R.P. Singh)

### ***Optogalvenic Studies of Rb***

The optogalvenic (OG) effect is the change in impedance of a gas discharge caused by resonant absorption of electromagnetic radiation. The changes in impedance manifest as current changes and can be detected as signal voltage across a suitable resistance connected in series with the discharge cell. Study of these signals gives information regarding population of various levels, electron density in the discharge and the details of ionisation processes that generate the OG effects.

We have carried out our experiments on a commercial hollow cathode lamp (Varian, Australia). The cathode material of the lamp is Rb with Nitrogen as buffer gas. The signals, ac modulations, were monitored by measuring the voltage across a resistor on the oscilloscope by blocking dc through a capacitor. While in earlier studies the applied dc voltage was varied in steps, we have managed to get a continuous variation of dc voltage by modulating the dc supply with a triangular function, obtained by a function generator with an amplitude of 30 V and a period of 100 Sec. The variation in the frequency of ac signal with applied dc voltage shows many new features hitherto unobserved in the earlier studies as continuous nature of variation of the dc voltage in our experiment covers the gaps left by discrete nature of variation in the earlier observations.

(Ranjit Singh and Duli Chand)

The research programme of the division are diversified and literally covers the whole gamut of space physics. They are broadly categorized under three major subgroups, namely, the middle atmospheric physics, upper atmospheric physics, including planetary and cometary atmospheric studies and laboratory astrophysics. The scientific results from the above research activities are given in the following sections.

## MIDDLE ATMOSPHERE

### *INDOEX Experiments over the Indian Ocean*

Measurements of  $O_3$ , NO, and CO over the Indian Ocean covering the latitude region of  $16^\circ N - 20^\circ S$  have been made during February 18 to March 30, 1998 as a first field phase of the INDOEX experiments. During this cruise, measurements were also made at south of the Inter-Tropical Convergence Zone (ITCZ) in the pristine air from southern hemisphere. Special efforts were made to measure NO with the help of an ultra sensitive instrument. The concentration of NO in a clean marine environment is extremely low in pptv range and is important in understanding the critical level of NO which decides the ozone production or loss. Average diurnal amplitudes of

NO and  $O_3$  were observed to be about 30 pptv and 6-7 ppbv (Fig.4.1), indicating features of cleaner environment during most of the cruise track.

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

### *Measurement of Surface $O_3$ and $NO_x$ at a Coastal Site*

Jointly with the Space Physics Laboratory (SPL), Trivandrum, we have initiated measurements of surface  $O_3$  and  $NO_x$  near the coast, from April 1997. The measurement reveals that there is a buildup of ozone during the day similar to the measurements over Ahmedabad and Gadanki even though the site is a coastal area where levels of pollutants are expected to be lower. The signature of the reversal in the wind direction during the evening is observed in ozone diurnal pattern. These measurements together with boundary layer measurements by SPL group will be useful in the study of its effect on ozone variations.

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

### *Evidence for Excess Aerosol Radiative Forcing Obtained over the Indian Ocean*

One of the crucial uncertainties in validating model predictions of climate change is, the role of aerosols in the radiation budget. While *Greenhouse Gases* are known to produce a positive forcing (warming), aerosols by scattering away the incoming solar radiation produce a negative forcing (cooling). The commonly accepted value for the negative forcing by sulphate aerosol for the northern hemisphere is about  $-1.1 \text{ W/m}^2$  which compensates by almost 50% the warming induced by greenhouse gases. We have obtained experimental evidence for the first time for the aerosol forcing to be of the order of  $-13 \text{ W/m}^2$  for every 0.1 increase in aerosol optical depth in the visible region, over remote Indian Ocean, unaffected by rapid fluctuations in aerosol characteristics which is common over land areas. The ship experiment conducted during January-February, 1997 was part of the Indian Ocean Experiment (INDOEX). Near the Indian coast (within 500 km), the forcing was still stronger by few  $\text{W/m}^2$ . We further found that the forcing exhibited a diurnal pattern,

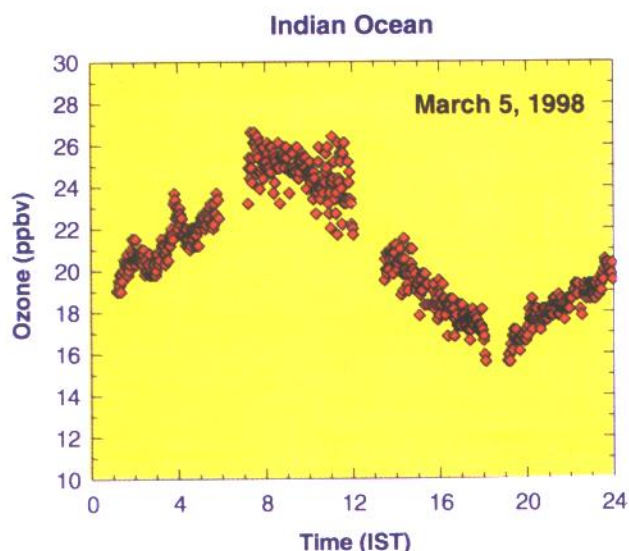


Fig. 4.1 A typical diurnal variation of surface ozone averaged over  $3.25^\circ N - 0.25^\circ S$  region during the INDOEX-FFP February-March, 1998 cruise.



and the average forcing came to around  $-5.2 \text{ W/m}^2$  which is much higher than the average value of  $-1.1 \text{ W/m}^2$  for the northern hemisphere. It is suggested that in addition to sulphate particles, large amount of mineral and carbonaceous particles produced over the adjoining land masses might be transported over this ocean region and the resultant spatial inhomogeneity in the distribution of aerosols around the globe could possibly be the reason for the observed large differences.

(A. Jayaraman)

### ***Rayleigh and Raman Scattering Observations using Nd:YAG Backscatter Lidar at Mt. Abu***

Atmospheric backscatter lidar is a powerful tool to remote sense the atmospheric properties up to about 90 km. A Nd:YAG laser based Rayleigh lidar system with 90 cm Cassegrain receiver telescope is in operation since 1996 at the Optical Aeronomy Laboratory situated at Gurushikhar, Mt. Abu at a height of about 1.7 km above MSL where the attenuation of the backscattered signal from high altitudes becomes minimum due to very low aerosol concentration at lower altitudes. Assuming hydrostatic equilibrium and perfect gas law distribution, density, temperature and the short period wave induced oscillations in the density profiles are derived. To overcome the limitations of Rayleigh Lidar technique at lower altitudes presently an additional channel is introduced in the receiver to detect the Raman scattered signal from nitrogen molecules at 607nm for the transmitted wavelength of 532 nm (second harmonic of Nd:YAG laser). By combining the two profiles from Raman scattering and Rayleigh scattering neutral number density and temperature profiles are obtained from as low as 3 km to as high as 90 km.

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

### ***Solar Cycle Dependence of Stratospheric Electrical Conductivity***

Data obtained from balloon-borne conductivity measurements during the Indian Middle Atmospheric Programme (IMAP) time frame, i.e. 1984-1994 reveal significant solar activity dependence of the stratospheric

electrical conductivity. Inspite of the measurements having been made by different techniques, there had been a reasonable agreement in the relative variation of conductivity in a given solar epoch, while the absolute magnitudes were never deviating more than 20%. Critical analysis of the data reveal larger conductivities by a factor of 1.5 during high solar activity periods. Though the conductivities are dependent on the masses of the charged particles and as well as their number densities since, there is no reason why the composition should change with solar activity, it is inferred that increase in the number density, essentially controlled by the solar cosmic rays, must be responsible for the enhancement in conductivity. This new result brings forth the solar control of the ion production even in the stratospheric heights.

(S.P. Gupta)

### ***Mesopause Scenario on Doubling of Atmospheric $\text{CO}_2$ Content***

In about five decades from now,  $\text{CO}_2$  content of the Earth's atmosphere is likely to be doubled. A model calculation shows that for this condition the temperature of the mesosphere will decrease by about 10 K,  $[\text{O}_2]$  and  $[\text{N}_2]$  will decrease by 40%,  $[\text{H}_2\text{O}]$  will decrease by 10%,  $[\text{O}]$  will increase by 25% and  $[\text{O}_3]$  will increase by 10% from their present levels. The effect of these changes at the mesopause region has been studied. The decrease of temperature and increase of  $[\text{H}_2\text{O}]$  will increase the percentage of clustered ions but simultaneous decrease of  $[\text{NO}]$  will tend to arrest this increase. The net increase of clustered ions will be by about 15%.  $\text{H}^+(\text{H}_2\text{O})_4$  and  $\text{H}^+(\text{H}_2\text{O})_5$  will be the predominant ions instead of  $\text{H}^+(\text{H}_2\text{O})_3$  and  $\text{H}^+(\text{H}_2\text{O})_4$ . The  $f = 1$  level (the height where the total number of clustered ions is equal to number of electrons) will go up by about 2 km. In the negative ion side,  $\text{HCO}_3^-(\text{H}_2\text{O})_n$  with  $n > 2$  will become the predominant negative ion instead of  $\text{O}_2^-$ . Also  $L = 1$  level (the height where number of negative ions is equal to the number of electrons) will go up by more than 5 km compared to the present level of 70 km. The overall effect of all the above changes on electron density will be a decrease of electron concentration by about 40%.

(D. K. Chakrabarty)



## **Long Term Trend of Total Ozone over India**

Ozone observations taken during the past 23-45 years by Dobson spectrophotometer at six stations, namely Kodaikanal (10° N, 77° E), Pune (18° N, 74° E), Ahmedabad (24° N, 72°E), Varanasi (25°N, 82°E), New Delhi (28°N,77°E) and Srinagar (34°N,74°E) have been analysed to examine the long-term trend of this species over the Indian subcontinent. An increasing trend over the years has been noticed at all the places, except at Varanasi, where a decreasing trend has been found. The cause of these trends could be attributed to the trends of ozone in the troposphere with the possible role of neutral dynamics peculiar to that location in the form of a reverse Hadley cell. This work was done with Dr. S. K. Peshin of IMD, New Delhi.

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

## **Comparative Study of Satellite and the Dobson Ozone Data over Indian Region**

The longest series of satellite ozone data is from Nimbus 7 Total Ozone Mapping Spectrometer (TOMS). A comparison of TOMS and Dobson data sets show that the former agrees with the latter at all the places except at Kodaikanal and Ahmedabad. Even after accounting for the pre-launch correction and the drift in the TOMS data, there remains some unexplained differences suggesting that certain localized peculiar features might be present over the Indian subcontinent.

(D.K. Chakrabarty, K.V. Pandya and P.K. Patra)

## **UPPER ATMOSPHERE**

### **Plausible Explanation for the Equatorial Temperature and Wind Anomaly (ETWA)**

A plausible explanation for one of the recently discovered equatorial phenomena, namely ETWA has been provided based on simultaneous measurements of ionospheric and thermospheric parameters by the Dynamic Explorer (DE-2) satellite. Both *ion drag* and *chemical heating* have been identified as responsible for the generation of temperature anomaly and their relative contributions estimated and the diurnal variation of ETWA

had been explained to a reasonable extent. During night-time the ion drag effects are absent due to the F-region dynamo which reduces the relative velocities of the ions and neutrals to negligibly small and therefore whatever differences were seen in the measured and expected neutral temperatures were ascribed to chemical heating. After establishing a relationship between the ionospheric densities and the chemical heating during magnetically quiet times, the ion drag which is proportional to the plasma densities and the zonal velocities was quantified and shown that the large scale temporal variabilities of the ETWA could reasonably be explained.

(R. Sridharan and T.K.Pant)

### **Parameterisation of Local and Non-local Processes into the MSIS-90 Model**

The equatorial and low latitude regions are replete with several local and non-local sources of energy along with their associated geophysical processes which are not usually accounted for by the present-day models. After duly accounting for the non-local processes, mainly through magnetic  $D_{st}$  variations, the local effects due to the Equatorial Temperature and Wind Anomaly (ETWA), were also worked out in finding the reasons for the significant deviations shown between the measured and model predicted neutral temperatures. Almost all the temporal variabilities have successfully been explained by additively correcting the model for the prevailing ionospheric/thermospheric conditions (**Fig.4.2**). With these improvements the MSIS-90 model has been shown to be able to represent the low latitude region reasonably well.

(T.K. Pant and R. Sridharan)

### **Daytime Rotational Temperature Estimates from Low Latitude Mesosphere**

The unique multiwavelength daytime photometer was operated from Kolhapur (16.8°N, 74.2°E Geographic, 10.6°N dip lat.) in a campaign mode for measuring the two distinctly separated rotational lines in the same vibrational band. The ratio of the measured intensities correspond to the rotational temperature which in turn is equal to the

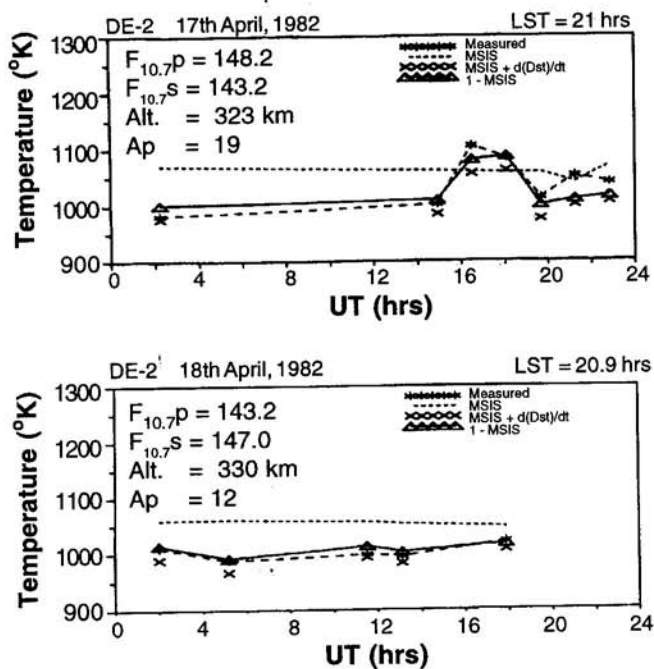


Fig. 4.2 The existing MSIS atmospheric model has been improved to represent the equatorial/low latitude region by accounting for local and non-local sources like the Equatorial Temperature and Wind Anomaly (ETWA) and the equatorial ring current associated precipitation and the dynamics.

neutral temperature around 85 km. The first results revealed that, the temperature showed significant variabilities by ~20%, often exhibiting a wavy structure with periodicities ~1-2 hrs (Fig. 4.3). Most of the time the temperature variations are centered around an average value which agrees with the prediction of the CIRA-86 model. But on occasions, especially during geomagnetically disturbed periods, one notices an overall shift in the average value indicating some amount of direct energy deposition in the upper mesosphere/lower thermosphere region.

(R. Sridharan, Alok K. Taori, R. Naryanan and N.K. Modi)

### Effect of Space-Weather Related Processes in the Low Latitude Thermosphere-Ionosphere System

A unique result has been obtained from low latitude pertaining to the January 6 Space-Weather event, when significant amount of energy was released from the Sun and when the magnetosphere got compressed to less than  $6 R_E$ . Daytime optical measurements were carried

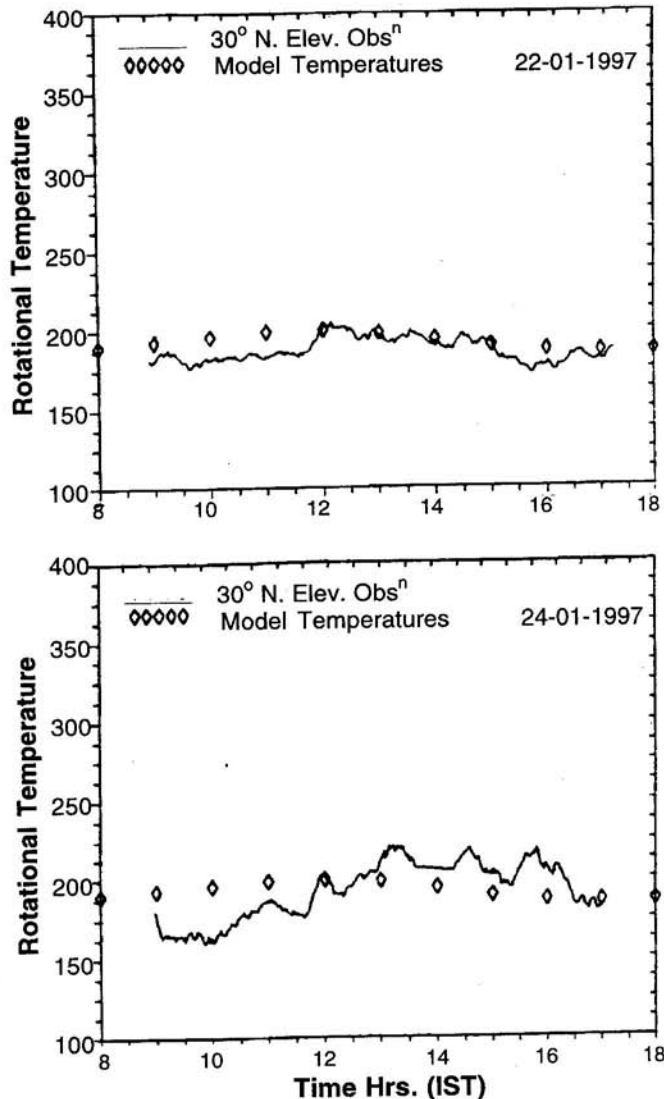


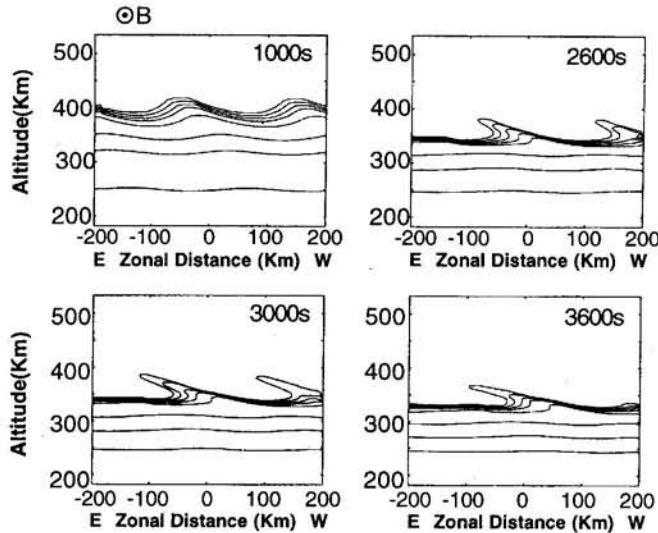
Fig. 4.3 The first ever measurements of OH rotational temperatures carried out from Kolhapur using the unique multiwavelength daytime photometer developed in PRL. The significant deviations from the CIRA model and also large scale wave activities with periodicities of 2 hrs. are clearly brought out.

out from Mt. Abu ( $24^\circ\text{N}$ ,  $73^\circ\text{E}$ ) during the above event. The OI 630.0 nm dayglow intensity registered an increase by a factor of 2.5 all through the day on 11 January, one day after the compression of the magnetopause. Noting that there had been no such increase one day before and after, and also as the ionospheric densities did not see any corresponding changes, it was suggested that, changes in the neutral composition/densities, must have resulted in the enhanced dayglow intensities. Represent-

tative model calculations do reveal that the changes in the altitude level of the turbopause above which molecular diffusion controls the density/composition at any given altitude, could have changed the composition in the region of airglow emission resulting in enhanced airglow. (R. Sridharan, Alok K. Taori, D. Chakrabarty, N.K. Modi and R. Narayanan)

### ***Investigation on the Suppression Mechanism of the Large Scale Plume Events in the Bottomside of the Ionosphere***

An investigation was carried out by means of a nonlinear numerical simulation model using different background ionospheric conditions for understanding the suppression mechanism of the large scale plume events (in VHF backscatter radar) on some nights and also the resurgence of a plume event at later time. It revealed that the development of long wavelength (200 km) perturbations can only be confined to the bottomside of the ionosphere in a localized region with the combined effects of shear in the zonal plasma drift and a nighttime westward electric field (**Fig. 4.4**). The variabilities in the occurrence pattern are shown to depend on the variabilities in the prereversal enhancement in the zonal electric field.



**Fig. 4.4** Temporal sequence of isoelectron density contours in zonal and vertical plane revealing the suppression of large scale bubble events to the bottomside of the ionosphere due to the combined effects of vertical shear in the zonal plasma drift and zonal electric field patterns.

Further, the resurgence of a plume event at a later time has been explained on the basis of confined structures as a pre-seed, subject to the presence of a source for a fresh instability. First evidence was presented for a source of fresh instability which actually could be a wind and/or a temperature disturbance launched hours earlier by a small substorm.

This work was done in collaboration with Prof. M.C. Kelley of Cornell University, USA.

(R. Sekar)

### ***Role of Ion Composition on the Rayleigh-Taylor Instability in the Nighttime Equatorial Ionosphere - Preliminary Results***

A linear theory of the Rayleigh-Taylor (R-T) instability analysis for a realistic equatorial ionosphere with two ion species is developed and an expression for the growth rate of the instability is obtained. In contrast to the case with a single ion constituent, the growth rate with two ion species depends on the number densities of the individual species. Combining this expression with nighttime equatorial F-region ionospheric conditions it is seen that (i) the growth of the irregularities in the ion densities, above the base of the F-layer mainly depends on the electron density gradient rather than the density gradient of the individual ion species, (ii) the overall growth rate of the R-T instability in the presence of two ionic species ( $\text{NO}^+$  and  $\text{O}^+$ ) gets reduced as compared to the growth rate of a single constituent.

(R. Sekar and E. Alam Kherani)

### ***Optical Imaging of Plasma Depletions over SHAR***

The all sky optical imaging system was operated from SHAR (13.67°N, 80°E) during January-April 1997 to study ionospheric plasma depletions through the 630 nm nightglow emission. It is seen that (a) the depletions showed large day-to-day variability, (b) the degree of depletion ranged between 30% and 70%, (c) the east-west cut across the depletion over SHAR revealed an asymmetry, (d) inter-depletion distance ranged between 250 and 300 km, (e) in addition to plasma depletions, sinusoidal wave like structures in the east-west direction



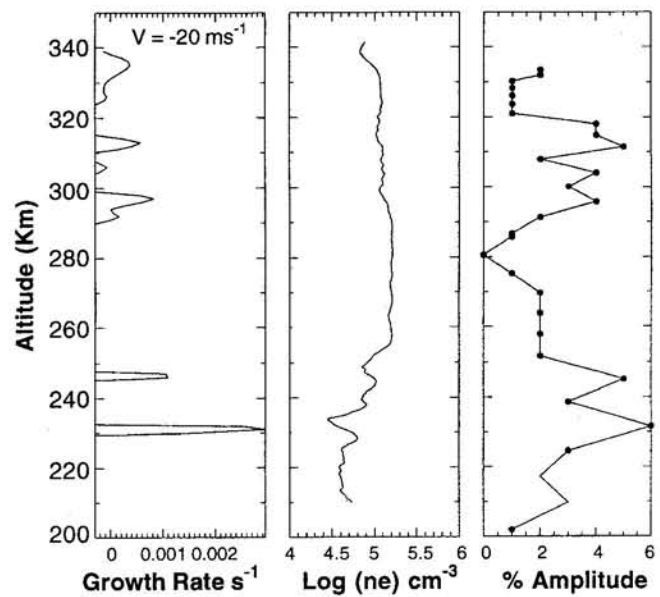
with scale sizes of 900-1300 km with amplitudes as large as 20% and (f) both eastern and the western walls of the plasma depletion were found to be unstable to small scale perturbations. It is suggested that the east-west asymmetry is a consequence of the increase in the eastward plasma drift with altitude, which results from the increase of the eastward neutral winds with altitude as often seen in Barium vapour release experiments.

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

### **Simultaneous in-situ Measurements of Electric Field and Electron Density Fluctuations During ESF**

Very intense electron density fluctuations, in the scale size range 200 m to 2 km, were observed by rocket-borne Langmuir probe flown from SHAR during a strong equatorial spread-F (ESF). Estimation of linear growth rate ( $\gamma_g$ ) was made by (a) using the actually observed gradient scale length over 4km, (b) an assumed downward wind of  $20\text{ms}^{-1}$  based on earlier vapour release observations, (c) estimating the westward electric field ( $0.8\text{mV/m}$ ) from the movement of the F layer on ionograms taken during the flight; (d) assuming a typical zonal wind value of  $100\text{ms}^{-1}$  and (e) taking other neutral parameters from MSIS-86 model. The calculated growth rate is maximum around 232km where the irregularities are observed to have maximum amplitude (**Fig.4.5**). The growth rate is positive only in those altitude regions where the observations indicate the presence of irregularities suggesting their generation through GRTI. A detailed analysis of relationship between the gradient scale size and  $\gamma_g$  was also performed which shows that out of the three destabilising mechanisms, namely, gravity, electric fields and neutral winds, the  $\vec{E} \times \vec{B}$  instability operating on negative gradients is responsible for the generation of irregularities on this occasion.

The electron density profile showed the presence of new type of irregularity in 165-175 km region. The scale sizes associated with these irregularities were in the range of 15m to 1km. Spectral analysis of these irregularities revealed that (a) perturbations in 15m to 1km had



*Fig. 4.5 The first panel shows the calculated net growth rate ( $\gamma_g$ ) of the irregularities, the middle panel depicts the smoothed electron density profile and the last panel shows the observed percentage amplitude of irregularities in the scalesize range of 200 m to 2 km.*

amplitude as high as 30-40% and (b) structures can be represented by single spectral slope with spectral index of  $-3.9 \pm 0.2$ . These irregularities cannot be produced by GRTI because at these altitudes GRTI would be highly damped due to very high ion - neutral collision frequencies. The excitation of gradient drift instability is also ruled out owing to presence of very weak gradients and very steep spectra for such scales. Some new mechanism must be invoked to explain these irregularities.

Two pairs of Langmuir double probes measured electric field fluctuations along ( $E_v$ ) and perpendicular ( $E_H$ ) to the spin axis of the rocket which was oriented at a few degrees off from the vertical. These constitute the first in-situ measurements during the fully developed phase of ESF from the Indian subcontinent. The irregularities were present not only at the base of F-region, but all through the F-region. The correlation between  $\delta n_e$  and  $\delta E_v$  was -0.76 in the region below the base, +0.90 around the base and -0.92 above the base. The correlation between  $\delta n_e$  and  $\delta E_H$  was very poor in all the three

regions. These observations are at variance with the observations in the American zone which showed strong anti-correlation between  $(\delta n_e)$  and  $(\delta E_V)$  and very poor correlation between  $(\delta n_e)$  and  $(\delta E_H)$  and the reasons for these sort of discrepancies are being studied in detail.

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

### ***Longitudinal Inequalities in the Equatorial Electrojet***

The two well marked longitudinal inequalities in the equatorial electrojet parameters in the Indian and American regions are: (a) the peak electrojet current density is located about 2 km higher in the American region with respect to its location in the Indian region and (b) the in situ observations of the peak current density show that it is about 10% higher in the Indian region with respect to that in the American region, which is contrary to the expectation based on the observed ground  $\Delta H$  variations in both the regions. In the present work, calculations of Pedersen, Hall and Cowling conductivities are made using the same plasma and neutral parameters along with actually observed ground magnetic field values from both the regions. It is shown here that the parameter  $R_i$ , which is the ratio of ion-neutral collision frequency to the ion-gyro frequency, is partly responsible for the altitude difference of peak current densities in both the regions. The second inequality can be understood if the ground  $\Delta H$  variations of both the regions are normalized to the same epoch of the solar activity. It is also shown that peak current density and peak Cowling conductivity are higher by 29% and 73%, respectively in the American region as compared to that in the Indian region. To examine the relative role of the electron density, the electric field and the magnetic field in contributing to the inequality in  $\Delta H$  variations (57%) in the American and Indian regions, geomagnetic H data for the period 1958-66 were examined at Huancayo and Kodaikanal along with  $f_o E$  data. It is found that although the electron density and the magnetic fields at the two locations are also different, the longitudinal inequality is caused primarily by the variations of higher electron velocities in the American region. This work was done in collaboration with Prof. R.G. Rastogi.

(H.S.S. Sinha and H. Chandra)

### ***Signal Processing Techniques as Applied to the Indian MST Radar***

During the past year three sets of tropospheric observations have been made. In order to evaluate the suitability of different signal processing techniques, the seldom used ability of the radar to record time series of the in-phase,  $I(t)$ , and quadrature,  $Q(t)$ , components of the received signals has been exploited. It has been found that the most appropriate weighting window to apply to  $I(t)$  and  $Q(t)$  prior to Fourier transformation is the Hanning. The use of the rectangular window leads to considerable overestimation of the spectral noise levels for the strongest radar returns. A comparison has been made of Time Domain Correction (TDC) and Frequency Domain Correction (FDC) of radar returns which remove unwanted contributions such as those from ground clutter. The former method removes systematic dc biases from  $I(t)$  and  $Q(t)$ . The latter, more common, technique replaces the near zero frequency components of the Doppler spectra with the averages of the adjacent values. This can also remove significant signal information from very narrow width spectra with near zero Doppler shifts. A separate campaign has been conducted in order to evaluate the response of the Sensitivity Time Control (STC) of the radar; this attenuates the signals from the lowest few kilometers of the atmosphere which might otherwise saturate in the high gain receivers. The variation of attenuation as a function of range has been found to differ to that which was expected.

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

### ***Escape of Non-thermal Ions from Martian Ionosphere***

A kinetic model to study the transportation of ions  $\text{CO}_2^+$ ,  $\text{CO}^+$ ,  $\text{O}_2^+$  and  $\text{O}^+$  from Martian ionosphere was developed earlier. These ions were bound to Mars' gravitational force due to their heavy mass. Their velocities are decreasing with the altitude. This model is extended now to investigate the flux and densities of  $\text{H}^+$  and  $\text{He}^+$  ions which get accelerated outward at 2000 K from the dayside ionosphere of Mars by large electrical force working against the gravitational force. In this calculation, the

velocities of ions  $H^+$  and  $He^+$  are increasing with altitude. These ions are blown out of the ionosphere due to non-thermal escape process. The calculations are in good agreement with the observations taken by Phobos 2 spacecraft which suggests that ions  $H^+$  and  $He^+$  are also escaping from the Martian ionosphere due to polar wind acceleration process similar to the other ions.

(S.A. Haider)

### Nightside Ionosphere of Mars

It has been found that Mars has a weak magnetosphere whose field lines are horizontal throughout most of the ionosphere except in the vicinity of the magnetic poles. The one dimensional continuity and momentum equations are solved to study the effect of magnetic field in the nightside ionosphere of Mars. The model is the same as used earlier to study the chemistry of the dayside ionosphere of Mars. The calculated results are found in good agreement with the experimental data obtained from Viking 1 and 2. The calculations show that the magnetic diffusion is an important loss process above about 160 km in the nightside Martian ionosphere. In the magnetized Martian ionosphere, the ion density reduces by an order of magnitude than that of an unmagnetized ionosphere (Fig. 4.6).

(K.S. Raina and S.A. Haider)

### Cometary Coma.

The observations of CI 1931A emission (which arises from  $2P\ 3s^1P^0 - 2P^2D$  transition in carbon atom) in the ultraviolet spectra of comets show that a large fraction of carbon atoms in the cometary coma are produced in the metastable  $^1D$  excited state. A coupled chemical transport model developed earlier is used to study the chemistry of  $C(^1D)$  atoms and the mechanism of production of CI 1931A in the near nucleus environment. The CI 1931A emission is found to be governed dominantly by the density distribution of CO and  $C(^1D)$ . The calculated results of this emission line will be useful for the future observation of comet P/Wirtanen, the target of ROSETTA mission.

(S. A. Haider)

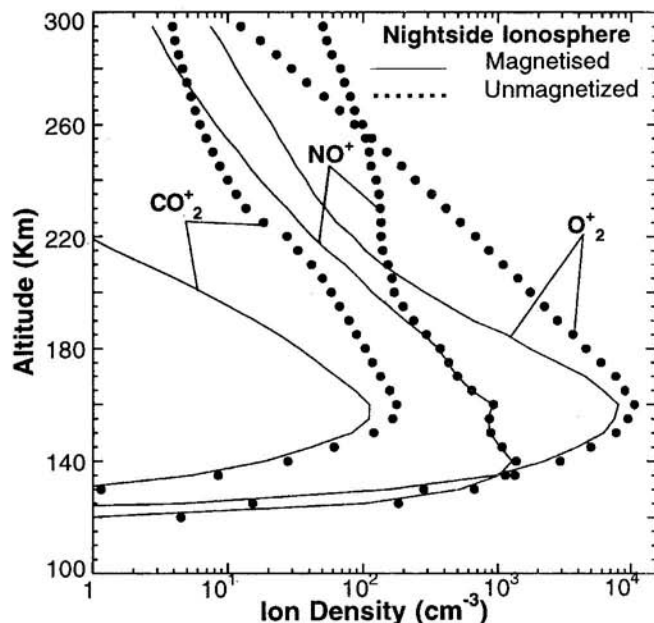


Fig. 4.6 Nightside ionosphere of Mars due to magnetized and unmagnetized conditions.

## LABORATORY ASTROPHYSICS

### Total Electron Scattering Cross Sections for Nitrous Oxide and Carbon Monoxide

Absolute electron scattering cross section for nitrous oxide and carbon monoxide at low electron energies have been estimated using laboratory measurements.

The cross section curves, as obtained are shown in Fig. 4.7, reveal two broad features. Though there are striking similarities, it has been found that the cross section values of carbon dioxide are smaller than those of nitrous oxide at almost all the electron energies below 10 eV. Secondly, resonance peaks have been found at different electron energies in the two cases. It is known that nitrous oxide is a polar molecule with a permanent dipole moment where as carbon dioxide is a non-polar molecule. It has been found that at smaller scattering angles, the differential cross sections are larger in case of polar molecules than those for non-polar molecules. Based on this, it is expected that the total cross sections would also be larger in case of molecules having permanent dipole moment and hence the differences are explained.

(P. Rawat, K.P. Subramanian, Vijay Kumar, A.P. Gohil, J.K. Dave and V.K. Lodha)



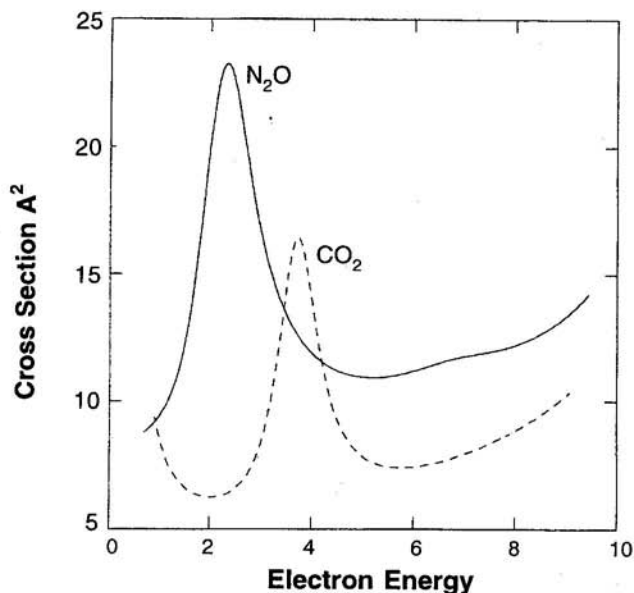


Fig. 4.7 Comparison of cross section curves for  $\text{CO}_2$  and  $\text{N}_2\text{O}$  at low electron energies.

### **Fluorescence and Lifetime Studies of NO in the First Predissociation Region**

The study of fluorescence excitation spectrum and the measurement of radiative lifetime for  $\text{NO}_2$  in the wavelength region of 460-510nm have previously been carried out. The measurements are now being extended to the lower wavelength region, i.e. 399-416nm which incidentally is the first predissociation region for  $\text{NO}_2$ . An excimer laser pumped tunable dye-laser is used to scan the wavelength in the specified spectral region. A fast photomultiplier and a fast sampling digital storage oscil-

loscope having a large band width are used to record the fluorescence excitation spectrum of  $\text{NO}_2$ .

$\text{NO}_2$  is known to photodissociate below 398 nm and predissociate at incident photon wavelengths ranging from 398 to 440nm. In this study, the excitation spectra and the time resolved fluorescence decay curves for  $\text{NO}_2$  at different pressures have been measured to study the effect of collisional quenching on the measured life times in this predissociation region. A detailed data analysis is in progress.

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

### **Pressure Dependence of Fluorescence Bands of Sulphur Dioxide**

Fluorescence excitation spectra of  $\text{SO}_2$  by photon impact have been obtained as a function of incident photon wavelength ranging from 210 to 232 nm at different pressures varying from 20 to 250milli torr in order to compute self-quenching rate constants for different fluorescence bands of  $\text{SO}_2$  in the above spectral region.

The experiment consists of an argon mini arc continuum light source, a 1-metre near normal-incidence grating monochromator, a beam splitter to monitor the incident photon beam intensity during the experiment, a fluorescence chamber, the collimating optics and the fast detection system. Detailed data analysis is in progress.

(I.A. Prajapati, K.P. Subramanian, Vijay Kumar, A.P. Gohil, I.T. Kripalani, J.K. Dave and V.K. Lodha)

The primary goal of the research programmes of the Earth Sciences and Solar System Division is to characterise the temporal evolution of the solar system objects Sun, Earth, Moon and the meteorites. This goal is achieved through precise measurements of the abundances of chemical and isotopic markers contained in selected constituent phases of these objects. The Division comprises of two areas, i. Oceanography and Climate Studies and ii. Solar System and Geochronology.

The areas of research of the Oceanography and Climate Studies area can be grouped broadly under two themes, (i) Palaeoclimate and Palaeoenvironmental studies based on continental and marine archives over various spatial and temporal scales and (ii) Oceanography and Geochemistry. In addition, efforts to model palaeomonsoon variations over the Indian region have been initiated.

## Palaeoclimates and Palaeoenvironment

### Speleothems

Speleothems, a cave calcite deposit can be used to retrieve palaeoclimatic information of the region in which they grow. Speleothem samples collected from Gupteswar cave, Orissa and Dandak cave, Madhya Pradesh were sub-sampled and analyzed for their  $\delta^{13}\text{C}$ ,  $\delta^{18}\text{O}$  compositions. The samples were also dated by radiocarbon. The isotopic compositions show remarkably similar variations

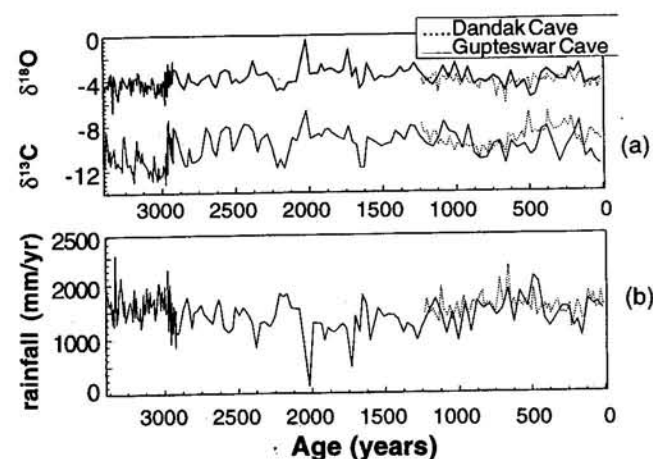


Fig. 5.1 (a)  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  vs. age plot for speleothems and (b) rainfall reconstruction using  $\delta^{18}\text{O}$  data

in the two samples, even though they are spatially separated by about ~ 100 km. The observed  $\delta^{18}\text{O}$  variations are too large to be explained by past cave temperature variations, hence the variations are attributed to changes in the  $\delta^{18}\text{O}$  of local rainfall. It is well known that the  $\delta^{18}\text{O}$  of precipitation in tropical sites is inversely correlated with the amount of precipitation, known as *amount effect*. Using this, the monsoon rainfall for the past ~ 3.5 ka has been reconstructed. This record (Fig. 5.1) shows that the monsoon rainfall fluctuated by  $\pm 22\%$  during this period. Efforts are on to verify this from speleothem  $\delta^{18}\text{O}$  records in Karnataka.

(R. Ramesh and M. G. Yadava)

### Stratigraphy and Palaeoenvironmental History of Thar Desert

The work on the DST sponsored Thar Desert Project was continued and several new results on the Quaternary history and Palaeomonsoon/Palaeoenvironmental changes in Thar Desert were obtained. These are :

**Aeolian Sequences :** Luminescence dating of aeolian sands and stable isotopic studies on pedogenic carbonates within a colluvial-aeolian sequence at Shergarh tri-junction in the Central Thar show that the Thar experienced an arid phase during 66-60 ka, normal monsoonal condition during 60-25 ka and arid condition during 25-10 ka.

Chronological studies on several dune profiles in the Thar indicated that contrary to the expectation of a stable climatic regime during the past ~ 15 ka, the region experienced fluctuating climatic regime in respect of aeolian accumulation. The principal periods of aeolian accumulation are 13 ka, 7 ka, 4 ka and 1.8 ka. The final phase of aeolian accumulation was at 800a in the eastern Thar and 500a in the western Thar. Anthropogenically caused aeolian activity after 300 a are clearly discernible at different places (Fig. 5.2).

**Lacustrine Sequences:** OSL studies on the silt/sand sequences on lake Malar coupled with AMS radiocarbon dating of pollen extracts indicate that the lake formed about 10 ka ago and dried up at about 5 ka ago. A fresh-

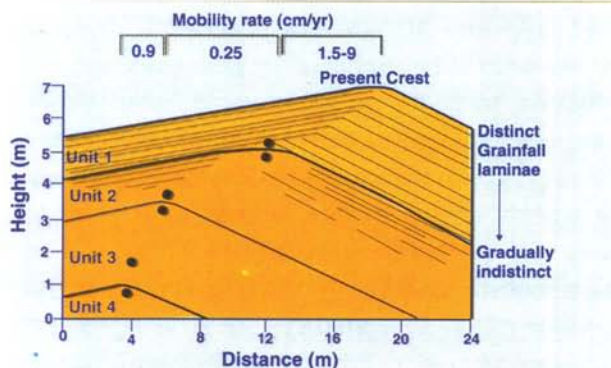


Fig. 5.2 Section diagram of the transverse dune at Khara. Circles show the sampling sites. TR numbers are for the IRSL samples

water phase existed at around 6-7 ka and fluctuating hydrological regime during 10-8 ka. The concordance of radiocarbon ages and OSL ages was seen.

**Calcretes:** The basal quaternary deposits in Thar are calcretes. During the past year considerable effort was expended to develop a methodology for dating these carbonates using the Electron Spin Resonance technique. A suite of samples was analyzed and the ages spanning 50ka - 2.4Ma were obtained which are stratigraphically consistent.

The studies in the Thar desert are part of a combined effort by the scientists of PRL, Ahmedabad; Delhi University, Delhi; Central Arid Zone Research Institute, Jodhpur; Deccan College, Pune; BARC, Bombay and IIT, Bombay.

(N. Juyal, A.J. Kailath, S. Kusumgar, P. Mishra, A.K. Singhvi and J.V. Thomas).

### **Chronology of Loess Accumulation in China**

IRSL studies of a loess-palaeosol sequence in China at the site Jhizhoutai was carried out to establish its chronology. The site was chosen as it is known to have a very high accumulation of ~ 40 m loess during the last glacial/interglacial cycle. Detection of Blake event within the lower soil horizon, provided an independent age control. The results obtained show that the mean life of

IRSL signal is ~ 70 ka and that of TL signal ~ 150 ka. This is the first direct determination of the mean life of these signals. The present results indicate that the loess accumulation was punctuated by several hiatuses confirming the results of our global synthesis of luminescence ages. This puts to question the validity of land-sea correlations using loess-palaeosol sequences.

This study was conducted jointly with scientists from Roorkee University, Royal Holloway College, University of London, and Silesian Institute of Technology, Gliwice, Poland.

(N. Juyal and A.K. Singhvi)

### **Palaeoclimate of the Nal Region from Illite Crystallinity Index**

Clay minerals, in particular the degree of crystallinity of illite, is useful to understand the climate at the time of their formation. Low values of crystallinity index (CI) indicate formation in low temperature and dry conditions, whereas high-CI values suggest formation in higher rainfall (wet), and temperature conditions.

In the Nal Sarovar core at all depths upto 25 m the illites are crystalline (index 0.14 - 0.43) except at 12.85 - 13.24 m (IRSL age ~ 50 ka) where they were poorly-crystalline (index 0.55 - 0.63). This is interpreted to indicate that after a continuous spell of aridity, there was a wet spell around ~ 50 ka B.P. The presence of red bed at this depth (12.85 - 13.24 m) supports the hypothesis of wet climate during this period.

Four new cores (10-30 m) raised from north and south of Nal Sarovar in the Nal region in June 1996 were also studied. Lithological and mineralogical studies on these confirmed the earlier suggested 3-stage model for evolution for the Nal region during the late Quaternary.

(S.K. Gupta, K. Pandarinath and Sushma Prasad)

### **Arabian Sea Sediments**

The aim of this study is to decipher monsoon induced changes of biological productivity through detailed chemical and isotopic measurements in dated sediment cores from the eastern Arabian Sea. Towards



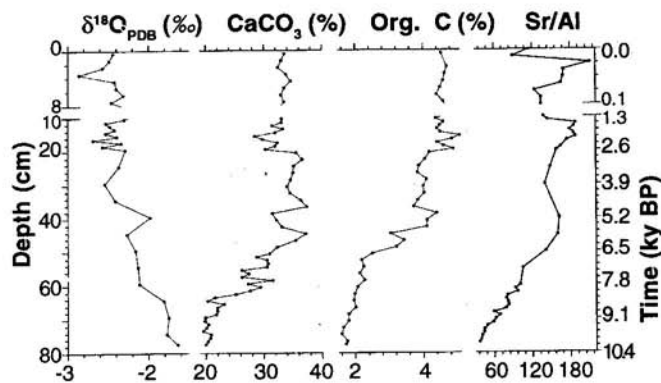


Fig. 5.3 Depth profiles of  $\delta^{18}\text{O}$ ,  $\text{CaCO}_3$ , OrgC and Sr/Al for the past ~10ka from a core in the Arabian Sea

this, about a dozen gravity cores were dated using  $^{210}\text{Pb}$ ,  $^{137}\text{Cs}$  and radiocarbon of planktonic foraminifera. Organic carbon and  $\text{CaCO}_3$  were measured in most of the cores to assess their burial rates and their variations during the past. These rates for the most recent period (Fig. 5.3) are high due to higher productivity and better preservation. Two of the cores, SS 2502G and SS 3268G5 off Mangalore have been taken for detailed palaeontological and stable isotopic studies. The  $\delta^{18}\text{O}$  in the top ~10 cm of the core which corresponds to the past century, correlates reasonably well ( $r = -0.6$ ) with rainfall in the region. Since high rainfall translates to high monsoonal intensity which can be correlated to higher upwelling, one expects an inverse trend between productivity-based-parameters and  $\delta^{18}\text{O}$ . Indeed such a trend has been observed during the period ~10 ka and ~2 ka. AMS radiocarbon measurements were done by Dr. A.J.T. Jull of the NSF AMS Arizona Facility.

(R. Agnihotri, R. Bhushan, M. Dixit, K. Dutta, R. Ramesh, A. Sarkar and B.L.K. Somayajulu).

### ***CO<sub>2</sub> in Phanerozoic Period : Evidence from Palaeosols of the Satpura Basin***

In Central India near Satpura region alluvial strata of ages between Permo-Carboniferous (290 Ma) and uppermost Cretaceous (~65 Ma) are excellently preserved. A number of calcic palaeosols have been identified within some of these strata. The  $\delta^{13}\text{C}$  composition of the soil carbonate is derived from soil- $\text{CO}_2$  which is an admixture

of atmospheric  $\text{CO}_2$  ( $\delta^{13}\text{C} = -6\text{‰}$  PDB) and plant respired  $\text{CO}_2$  ( $\delta^{13}\text{C} = -25\text{‰}$  PDB). Therefore, it is possible to determine atmospheric  $\text{pCO}_2$  from  $\delta^{13}\text{C}$  composition of the palaeosol carbonates if the character of the soil type can be identified.

Palaeosol carbonates were collected from Motur, Denwa and Bagra Formations of the Satpura basin and analysed for their carbon isotopic composition. The derived  $\text{pCO}_2$  values are : 2100 ppmV, 2300 ppmV and 2600 ppmV for the three formations corresponding to Permian (280 Ma), late Triassic (220 Ma) and Jurassic (200 Ma) periods respectively. This indicates that the partial pressure of atmospheric  $\text{CO}_2$  was 7-8 times the present day value during these three periods.

### ***Climatic Change during the Last Glacial Stage in the Higher Central Himalaya : Stable Isotopic Signatures***

High resolution  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  measurements on carbonate phases of sediments from a relict lake at Goting in Central Himalaya provide a unique record of the climatic changes during the last glacial stage. The sediment column is about 20 m thick and has alternating bands of laminated ash grey horizons capped by pale yellow limonitic bands, 5 to 10 cm thick. The sediments are of typical glacial lake environment where the yearly cycles of sedimentation are preserved. Their repeated occurrence at regular intervals suggest cyclicity in the length of winter and summer during the glacial time. This is reflected in the depleted  $\delta^{18}\text{O}$  values of samples from the limonitic bands and enriched values for the ash grey layers.  $^{14}\text{C}$  dating of the sediments suggests that the deposition commenced around 40 ka BP and continued till the Glacial Maximum at about 20 ka BP.

In addition, the variation of  $\delta^{18}\text{O}$  with age suggest that prior to the Last Glacial Maximum the climate was unstable compared to the post LGM era because of fluctuations in the solar insolation and the monsoonal precipitation. This observation is well supported by records from the Arabian Sea sediments by other workers.

(S.K. Bhattacharya, P. Ghosh, Navin Juyal, R.K. Pant and M.G. Yadava).

## Glacio-Chemical Studies

The glaciers of the Himalaya have long been considered as an archive for providing high resolution records of the past environment and climate from Central Asia. Recognising this, detailed chemical analysis of the upper 7m snow and ice from Dokriani-Barnak (DB) glacier, Garhwal Himalaya, has been carried out. This study supplements our earlier work on the Chhota Shigri (CS) glacier, Central Himalaya.

The abundances of the major ions in snow samples, collected during May-June, 1994, are systematically lower than those in the previous year, October-November, 1993. In contrast, the ionic ratios (normalised to Na) are relatively higher in the 1994 snow. This seasonal trend suggests the differences in the sources and chemical loading of the air masses. A comparison of the chemical data reveals that the concentrations of Na, K, Cl and  $\text{NO}_3$  in the surface snow from the DB glacier are quite similar to those in the CS glacier (1987 snow), but the abundances of Ca, Mg and  $\text{SO}_4$  are two to three fold higher in the DB glacier. This regional trend could be due to increased levels of input from desert in recent years and influences of the local anthropogenic sources. The concentrations of the major ions (except  $\text{NO}_3$ ) are, on an average, 5 to 15 times higher in these low-altitude Himalayan glaciers than in the Biafo glacier (4650-5500m) in Karakoram. These differences are suggestive of greater influence of monsoonal sources of moisture in the southern slopes of the Himalaya. The chemical records, thus help to identify the sources of moisture and distribution of chemical species in the atmosphere.

(V.N. Nijampurkar, D.K. Rao and M.M. Sarin)

## Palaeoclimate Modelling

Palaeoclimate data from the Indian region indicate that the monsoon circulation over south Asia has undergone considerable variations during the past. Changes in the Sun-Earth geometry are the major cause of such variations. We have used the NCAR (National Centre for Climate Research) CCM2 (Community Climate Model 2) to simulate July climate corresponding to the orbital parameters (eccentricity, tilt and precession) at 6, 9 (with

modern sea surface temperatures, SST) and 18 ka (glacial age SST). The results show that the monsoon circulation strengthened considerably during 6 and 9 ka, as observed in palaeoclimatic records, whereas for the 18 ka simulation, there was no change in the monsoon precipitation over India, contrary to observations. These results were then compared with earlier simulations of palaeomonsoon using CCMO (CCM2 used by us is an advanced model with improved parameterisation of physical processes). There were quantitative difference between the two results, and it was found that the differences are mainly due to the differences in the simulation of modern climate (control runs) between the models. Part of the differences is due to the resolution and part is due to the parameterisation of physical processes. We are at present trying to decouple these two aspects by further simulations. This work was done in collaboration with scientists at the Centre for Atmospheric and Ocean Sciences, Indian Institute of Science, Bangalore.

(D. Jagadheesha and R. Ramesh)

## Oceanography and Geochemistry

### *Radiocarbon in the Arabian Sea and Overhead Air*

This project, with partial support from the Department of Ocean Development (DOD) to study circulation of waters in the Arabian Sea using radiocarbon (cosmogenic and bomb-produced) was completed. Re-occupation of three GEOSECS stations in the region provided an opportunity to assess the temporal variations in the distribution and inventory of bomb radiocarbon over two decades. The bomb  $^{14}\text{C}$  inventories at the three GEOSECS stations during 1995 show that in the northern and central stations they are by and large same whereas in the southern stations it is about 20% higher compared to the GEOSECS values of 1978.

The air sea exchange rates of  $\text{CO}_2$  estimated from the bomb  $^{14}\text{C}$  inventory are in the range of 6-12 mole/ $\text{m}^2/\text{a}$ ; the higher values are typical of regions influenced by the penetration of the Red Sea Water.

The  $\Delta^{14}\text{C}$  of deep water (>2000m) measured during 1994-95 ranged from -187‰ to -210‰ that are enriched

by 20% compared to the GEOSECS values. This may lead to the possibility of using  $^{14}\text{C}$  along with salinity and temperature to decipher decadal changes in deep waters of the world oceans. Dr. P.V. Narvekar of NIO, Goa collaborated in some of these studies.

(R. Bhushan, S. Chakraborty, S. Krishnaswami and B.L.K. Somayajulu)

### ***$^{234}\text{Th} : ^{238}\text{U}$ Disequilibria, Particle Scavenging and Carbon Export in the Arabian Sea : JGOFS Results***

The determination of export flux of carbon from surface to deep waters in the Arabian Sea is a topic of considerable interest and we addressed this issue through measurements of  $^{234}\text{Th} : ^{238}\text{U}$  disequilibria in several vertical profiles from the upper 100m as a part of our national JGOFS(India) programme (partially supported by the Department of Ocean Development). Free floating sediment traps were also deployed at depths between 100-300m to compare the data from the water column profiles.

The temporal and spatial distribution of dissolved  $^{234}\text{Th} : ^{238}\text{U}$  disequilibria yields a residence time of about 30 days for the  $^{234}\text{Th}$  removal from dissolved to particulate pool. The export fluxes of  $^{234}\text{Th}$  vary as a function of primary production for the same season. The carbon export fluxes, derived from the  $^{234}\text{Th}$  export flux and  $\text{C}/^{234}\text{Th}$  ratio in the trap material at some of the sites are higher than those measured using sediment traps at 130m. These observations raise the question of differential cycling of the organic carbon and  $^{234}\text{Th}$  from the settling particulate matter. This issue needs to be sorted out for proper application of  $^{234}\text{Th} : ^{238}\text{U}$  system as a global survey tool for determining carbon export. Attempts are underway to use the water column POC (Particulate Organic Carbon) inventory as a representative index for  $\text{C}/^{234}\text{Th}$  ratio, on both temporal and spatial scales. Collection of settling particulate matter using sediment traps is done in collaboration with V. Ramaswamy, NIO, Goa.

(R. Rengarajan and M. M. Sarin)

### ***Vertical Fluxes of U-Th Series Nuclides Through the Water Column of the Bay of Bengal***

Application of reactive radionuclides as tracers to study the processes of particle scavenging and their kinetics is of prime interest in regions characterised by intense variability in particle fluxes. In this context, the Bay of Bengal is an important marine region where large seasonal changes in particulate fluxes are known to occur due to variations in river discharge and productivity.

Time series samples of settling particles, collected during the sediment trap experiments in the Bay of Bengal have been analysed for  $^{210}\text{Pb}$  and Th isotopes ( $^{228}\text{Th}$ ,  $^{230}\text{Th}$  and  $^{232}\text{Th}$ ). These samples were made available to us by V. Ramaswamy of NIO. Particle fluxes collected by the traps over a two year period, exhibit both intra and inter-annual variations. The important results of this study are : (i) at the northern site both  $^{230}\text{Th}$  and  $^{210}\text{Pb}$  are removed from the water column by vertical scavenging, (ii) at the central Bay of Bengal, there is evidence for particle focusing in the deep trap, and (iii) the  $^{210}\text{Pb}$  flux in the shallow and deep traps show variations coupled to mass flux which is known to be tied to monsoon cycles and associated sediment discharge and productivity.

(T.K. Dalai, S. Krishnaswami and M.M. Sarin)

### ***Black Shales from the Himalaya : Re-Os Isotopic Studies***

A programme to analyse black shales from the Himalaya for their Re-Os isotope systematics was initiated. This study aims to: (i) determine the chronology of the black shales and (ii) assess their role in the  $^{187}\text{Os}/^{186}\text{Os}$  evolution of the oceans since the Cenozoic. Preliminary data from a black shale outcrops show that Os and Re concentrations vary over two orders of magnitude, Os ~ (0.04-13) and Re ~ (2-250) ppb with  $^{187}\text{Os}/^{186}\text{Os}$ , 8-110. Two of the Mussoorie samples collected from the same horizon yield model ages of ~ 600 Ma, consistent with the Rb-Sr age reported for black shales from the region.

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



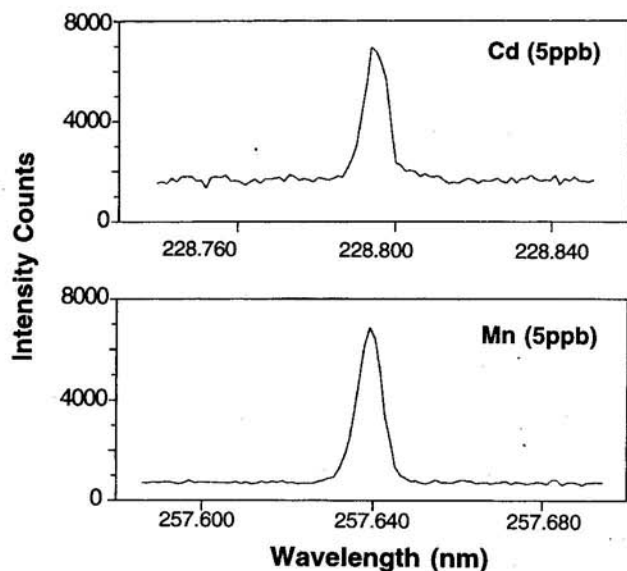


Fig. 5.4 Peak profiles obtained by an Ultrasonic Nebulizer for emission signals of Mn and Cd from 0.1% NaCl aqueous solution

### **Analysis of Trace Metals in Natural Waters by ICP-AES using Ultrasonic Nebulizer**

Routine measurements of some transition metals (V, Cr, Mn, Fe, Co, Ni, Cu, Zn) and refractory elements (Al, Ba), at parts per billion (ppb) level, in rivers and groundwaters have been achieved using Inductively Coupled Plasma-Atomic Emission Spectrometer (ICP-AES). The sample is introduced in the ICP, without any preconcentration step, using an Ultrasonic Nebulizer. Several test analyses were made to optimise various parameters and sensitivity (detection limit) in the range of 0.02 to 0.1 ppb has been achieved. An emission signal at 5 ppb level in 0.1% sodium chloride matrix is easily measurable for most of the transition metals (Fig.5.4). The technique is ideally suited for the analysis of metal contaminants in drinking waters.

(M. Dixit and M.M. Sarin)

### **Carbonatites**

A new carbonatite body from Samchampi, Assam was sampled for its stable carbon and oxygen isotopic compositions. The  $\delta^{18}\text{O}$  values fall in the range 7.0 - 9.0‰

proving the magmatic nature of Samchampi carbonatites. However, the  $\delta^{13}\text{C}$  values are higher than those expected for primary carbonatites suggesting that the primary magma had a  $\delta^{13}\text{C}$  value  $\sim 1.5\%$  higher than that of the average mantle. The mantle source region for this magma was probably contaminated by subducting oceanic crustal carbon. Similar observations were made by us earlier for the Sung Valley carbonatites. It appears that many of the carbonatite bodies in the Assam - Meghalaya Plateau bear signature of contamination of the source region by the subducting crustal carbon. This work was done in collaboration with scientists of the Geological Survey of India, Assam.

(R. Ramesh and J. S. Ray)

### **National Radiocarbon Facility**

A graphite extraction line for target preparation for accelerator mass spectrometry was developed, fabricated and tested. This maiden effort in India will enable extraction and measurement of  $^{14}\text{C}$  activity in samples containing less than 1 mg carbon and will subsequently enhance India's capability in radiocarbon dating.

Evidence of palaeoenvironmental changes during the Holocene from the Lower Mahi basin of western India has been documented. The  $^{14}\text{C}$  ages obtained on these marine mud horizons show that between 3600 and 1700a BP the sea level was higher than at present. The geomorphic evidence suggests that a late Holocene uplift has played a significant role in lowering the relative sea level to its present position. This work is in collaboration with scientists from the MS University, Baroda.

35 samples pertaining to different geological and archaeological problems were analysed for age determination. These include samples from relict lake at Goting in Central Himalaya and speleothems from Akalagavi cave, Karnataka. Based on detailed charcoal dating, various artifacts from 'Watgala' neolithic and megalithic site in Karnataka has been dated between 2000 to 4500a BP.

(S. Kusumgar and M. G. Yadava)



## Solar System and Geochronology

### ***<sup>26</sup>Al as a Heat Source in the Early Solar System: Evidence in Piplia Kalan Eucrite***

The short-lived radionuclide <sup>26</sup>Al (mean-life = 1 million years) has been postulated by Urey in 1955 as a source of heat, sufficient to cause early melting and differentiation of planetesimals. Since then the presence of <sup>26</sup>Mg excess due to decay of <sup>26</sup>Al has been documented in Ca-Al-rich Inclusions (CAIs) and chondrules, but attempts to demonstrate the presence of <sup>26</sup>Al in differentiated meteorites have so far remained unsuccessful. The Piplia Kalan eucrite, a differentiated meteorite, that fell in Rajasthan in 1996 has been shown to be extremely old based on Sm-Nd and Pu-Xe ages. We have measured Al-Mg isotopic composition in this meteorite to further investigate the role of <sup>26</sup>Al in early melting of parent bodies of the differentiated meteorites.

One thin section (PK-97-1) was examined using a Cameca SX electron microprobe. The major minerals are plagioclase (An<sub>95</sub>) and Ca-rich and Fe-rich pyroxenes; chromite and ilmenite are also present as minor constituents. Coarse-grained plagioclase and pyroxene crystals were studied for Al-Mg isotopic composition using a Cameca ims-4f ion microprobe. The results of this study

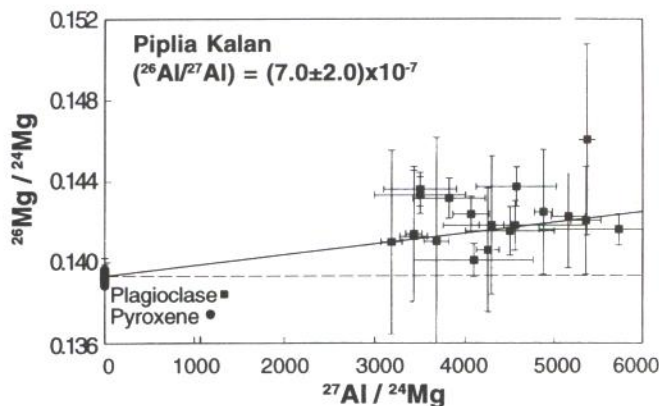


Fig. 5.5 Mg-Al evolution diagram for Piplia Kalan eucrite. Measured <sup>26</sup>Mg/<sup>24</sup>Mg values in plagioclase and pyroxene plotted as a function of <sup>27</sup>Al/<sup>24</sup>Mg values. The value of initial <sup>26</sup>Al/<sup>27</sup>Al at the time of formation of Piplia Kalan is obtained from the slope of the best-fit correlation line is  $(7.0 \pm 2.0) \times 10^{-7}$ . The horizontal line represents the value of reference <sup>26</sup>Mg/<sup>24</sup>Mg. All errors are  $2\sigma_m$ .

show that <sup>27</sup>Al/<sup>24</sup>Mg value ranges from 3000-6000 in plagioclase with excess <sup>26</sup>Mg/<sup>24</sup>Mg values varying from 6‰ to 48‰. Our data yield initial (<sup>26</sup>Al/<sup>27</sup>Al) value of  $(7.0 \pm 2.0) \times 10^{-7}$  (Fig.5.5). This study provides a strong evidence for the presence of live <sup>26</sup>Al at the time of formation of the Piplia Kalan eucrite and suggests a lapse of ~5 Ma between the formation of CAIs and this meteorite. These results suggest that <sup>26</sup>Al could have played an important role as a heat source in the formation of differentiated meteorites.

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

### ***Boron Isotope Composition in Early Solar System Objects***

Boron isotopic composition ( $\delta^{11}\text{B}$ ) in bulk samples of meteorites and lunar rocks does not vary by more than  $\pm 10\%$  relative to the NIST standard SRM 951. However, large variations ( $\pm 50\%$ ) within individual meteoritic chondrules have been reported. Incomplete processing of spallation-reaction-produced B in the protosolar molecular cloud fragment has been suggested as a plausible cause for these large variations. If true, records of B isotopic heterogeneity should also be found in the Ca-Al-rich refractory inclusions (CAIs) whose formation preceded that of the chondrules. In the present study we

have measured B isotopic composition in a single CAI (E44) from the Efremovka CV3 chondrite.

All the analyses were carried out using a Cameca ims-4f ion microprobe. A fused glass (GB-4) with a B content of 970 ppm and  $\delta^{11}\text{B} = -12.9\%$  (relative to SRM 951) was used as a standard. The results obtained from this study indicate low B contents for all the refractory silicate phases in E44. Anorthites have a relatively higher B content ( $\sim 0.3\text{--}1.5$  ppm) relative to melilite and fassaite ( $0.1\text{--}0.4$  ppm). The measured  $^{11}\text{B}/^{10}\text{B}$  ratios obtained from six analyses conducted on four anorthite grains did not reveal any significant variations. The  $\delta^{11}\text{B}$  values corrected for instrument fractionation are close to normal within the measurement error ( $1\sigma \sim 8\%$ ). The anorthites in the Efremovka CAI E44 do not have large-magnitude B isotopic anomaly reported for other meteoritic chondrules. Whether this observation suggests a complete homogenization of B isotopic composition during the formation of E44, a type B-1 CAI, or indicate a nearly homogeneous distribution of B isotopes in the solar nebula needs further scrutiny.

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

### ***Light Nitrogen in Mars Mantle?***

Most of the martian meteorites show noble gas isotopic signatures of the martian atmosphere, while only a few of them show nitrogen signature representative of martian atmosphere. This is most likely due to the preponderance of other N components in these meteorites. We have investigated N and Ar in the martian meteorite Shergotty, to decipher the nature of its N components. The  $\delta^{15}\text{N}$  starts at  $8\%$  in low temperature release and drops down to  $-39\%$  in the melting step. The total N content is 2.7 ppm. At least two N components, a minor component with heavy N (probably representing martian atmosphere) and a dominant component with light N (most likely of magmatic origin), are needed to explain these results. Such light N is also seen in Chassigny, another martian meteorite, whose noble gases represent an almost pure mantle component of Mars. The  $\text{N}/^{36}\text{Ar}$  ratio of Shergotty is  $4.9 \times 10^{-7}$ ; this is much lower than the ratio of  $5 \times 10^{-5}$  found in EET 79001,C (which supposedly hosted pure martian atmosphere) but is similar to that

measured in Chassigny. These facts indicate that most of the N in Shergotty could also be of magmatic origin and strongly suggest a light nitrogen isotopic composition for the mantle of Mars.

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

### ***Studies of Recently Fallen Indian Meteorites***

In a strange coincidence, three rare type of meteorites (an enstatite chondrite and two basaltic achondrites, a howardite and an eucrite) have fallen during a span of 5 years (1991-1996) within a distance of  $\sim 200$  km from each other in the semi-desert region of western Rajasthan. Studies of Piplia Kalan eucrite, revealed that it is a non-cumulate monomict breccia having diverse texture and it formed very early making it one of the oldest eucrites.

The Lohawat howardite fell on 30 October, 1994 at about 11 p.m. IST at Lohawat village in western Rajasthan. It is a heterogeneous polymict breccia with a large variety of lithic fragments. Preliminary chemical analysis gives bulk composition of Fe (15.15%), Mg (9.28%), Al (4.22%), Ca (4.73%), K (0.0267 - 0.0366%) and Na (0.26%); these values are typical of howardites.  $^{22}\text{Na}$  and  $^{26}\text{Al}$  activities are found to be  $(46 \pm 5)$  dpm/kg and  $(77 \pm 4)$  dpm/kg respectively. The cosmic ray track density is found to vary between  $0.7$  to  $6 \times 10^6/\text{cm}^2$ . Further work to determine the cosmic ray exposure age, trace element abundance pattern etc. is in progress.

The Didwana-Rajod meteorite fell at Rajod, near Didwana in western Rajasthan on 12 August, 1991 at about 10 p.m. IST. Mineralogical and petrological studies indicate that it consists of enstatite, iron metal and troilite with abundant chondrules ( $0.1 - 5$  mm). Bulk chemical composition of the meteorite is: Fe (31.77%), Mg (14.08%), Al (1.05%), Ca (1.12%), K (0.086%) and Na (0.68%). Based on varying degree of metamorphic degradation of chondrules, presence of ortho-enstatite and mg # of 0.5, the meteorite can be classified as an enstatite chondrite of type EH5. Cosmic ray track densities in a few spot samples taken from the surface region of the recovered meteorite are similar  $(6\text{--}7) \times 10^5/\text{cm}^2$ , indicating a nearly uniform atmospheric ablation. Near absence of  $^{60}\text{Co}$  indicates that the meteorite has experienced a low fluence



of thermal neutrons suggesting a small preatmospheric size.

(N. Bhandari, S. Chakraborty, M.H. Dixit, A.D. Shukla, P.N. Shukla and Suthar, K.M.)

### Nitrogen in Mantle Xenoliths

Nitrogen in the present day atmosphere amounts to only about 1 ppm, (with  $\delta^{15}\text{N}=0\text{‰}$ ), towards the total N inventory for the Earth, while evolutionary model predictions suggest a value of several ppm of N with negative  $\delta^{15}\text{N}$  for the whole earth. This requires that most of the N has been either lost from the atmosphere at an early time or still locked up inside the Earth. A determination of the mantle N composition is thus very crucial for a proper understanding of the N inventory of the Earth. Noble gas components of the mantle reservoir have been well characterised in the ultramafic xenoliths and we have carried out the first simultaneous study of N and noble gases in mineral separates from ultramafic xenoliths (San Carlos, Arizona) to understand the N systematics in the mantle.

The noble gas isotopic ratios  $^{20}\text{Ne}/^{22}\text{Ne}$ ,  $^{40}\text{Ar}/^{36}\text{Ar}$  and  $^{129}\text{Xe}/^{132}\text{Xe}$  clearly show the presence of the mantle component in these samples. N contents range from 0.1 to 1.5 ppm. The release pattern of  $\delta^{15}\text{N}$  shows the presence of three components: an air like component at low temperature, a heavy N component at intermediate temperatures and a light N component at melting step. On a plot of  $\delta^{15}\text{N}$  vs.  $^{40}\text{Ar}/^{36}\text{Ar}$  (Fig. 5.6) the data again fall in the field represented by the three components: degassed mantle (DM:  $\delta^{15}\text{N} \leq -15\text{‰}$ ), air saturated water (ASW:  $\delta^{15}\text{N}=0\text{‰}$ ) and recycled sediment (R:  $\delta^{15}\text{N} \geq 15\text{‰}$ ). Mixing calculations show that nitrogen from recycled sediments contributes ~37% to the mantle source for the San Carlos xenoliths.

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

### Carbonatite Magmatism at Stratigraphic Boundaries and Mass Extinction

The eruption of several continental flood basalts during the last 300 million years have been linked to major mass extinctions due to environmental changes at geo-

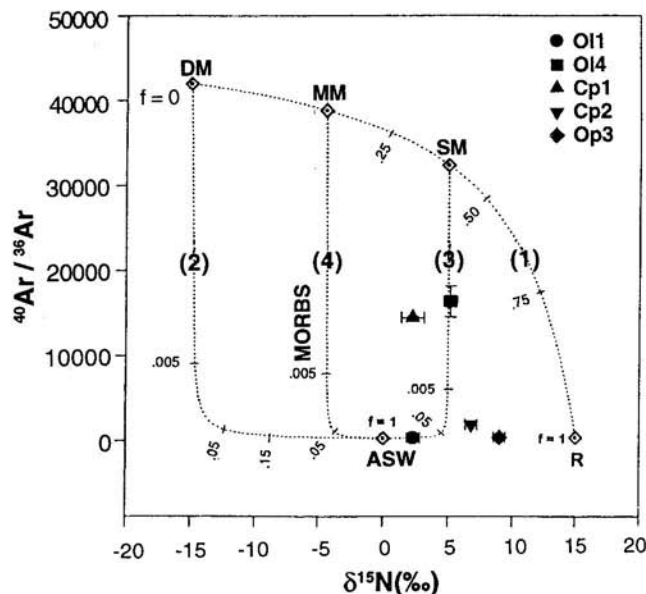


Fig. 5.6 A plot of  $^{40}\text{Ar}/^{36}\text{Ar}$  against  $^{15}\text{N}$  for different minerals from the San Carlos samples. ASW (Air saturated water), DM (Pristine Degassed Mantle), M (present day MORB Mantle), R (recycled sediments) and SM (San Carlos Mantle) are the various (N, Ar) end-members, the dotted lines (1, 2, 3 and 4) being the binary mixing curves between these end-members. Scale on each of these mixing curves represents the fraction (f) of the low  $^{40}\text{Ar}/^{36}\text{Ar}$  end-members.

logical boundaries. However, the ages of the most intense pulses of these flood basalts often do not coincide with the boundary events. We propose that the carbonatite-alkaline magmatic activities associated with flood basalt volcanisms, which have not been considered earlier, are a significant cause of environmental changes at these boundaries. For example, geochronological data indicate that most of the carbonatite-alkaline activities of Deccan province coincided with the Cretaceous/Tertiary boundary. Carbonatite-alkaline complexes associated with other Phanerozoic flood basalt provinces of the world for which information is available were also emplaced at the geological boundaries. A conservative calculation for the Deccan province shows that these activities, though volumetrically minor, can inject very high amount of  $\text{CO}_2$  and  $\text{SO}_2$  into the atmosphere (Fig. 5.7) in a very short time unlike the flood basalts which have extended period of formation of several million years. We propose that these activities could have enhanced the catastrophic

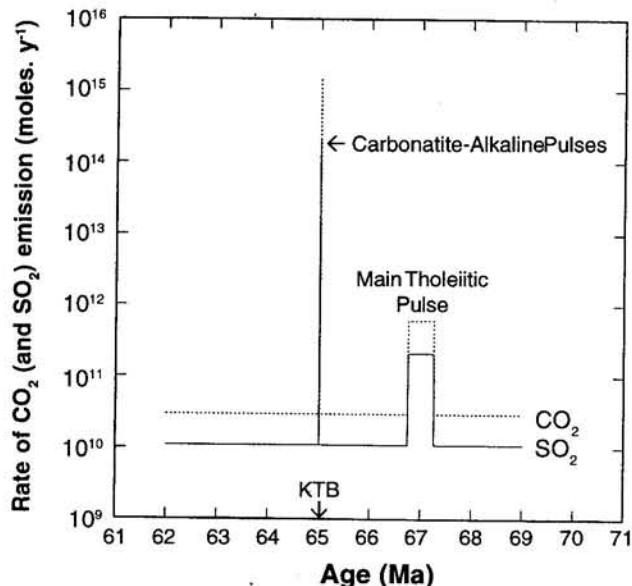


Fig. 5.7 Estimated  $\text{CO}_2$  (dotted line) and  $\text{SO}_2$  (solid line) release patterns of Deccan flood basalts and the associated post main tholeiitic pulse carbonatite-alkaline complexes. The background release rates of flood basalt are  $3 \times 10^{10}$  and  $1 \times 10^{10}$  moles/y respectively for  $\text{CO}_2$  and  $\text{SO}_2$  and that for the most intense pulse are  $6 \times 10^{11}$  and  $2 \times 10^{11}$  moles/y. Carbonatite-alkaline activities at 65 Ma released  $\text{CO}_2$  and  $\text{SO}_2$  at rates of  $1.4 \times 10^{15}$  and  $2 \times 10^{14}$  moles/y respectively. The arrow marks the Cretaceous/Tertiary boundary (KTB).

effects of the ongoing flood basaltic eruptions by rapidly pumping the destructive agents into the atmosphere.

(Kanchan Pande, J. S. Ray and T.R.Venkatesan)

### **Geochemical Studies of Anjar Basalts and Intertrappeans**

We have studied basalt samples of known ages from the Anjar flows (Kutch, Gujarat) that erupted close to the K/T event in an effort to quantify the possible contribution of Deccan volcanism to the Ir budget observed at the K/T boundary (KTB). A few measurements of Ir in samples of Deccan basalts, which are mostly tholeiitic, have been reported with their iridium concentration ranging between 6 and 26 pg/g. This can account for only 1 - 2 % of the Ir observed at KTB. We have now measured Ir in the alkaline basalts from Anjar, some of which (e.g. Flow 3, 4) have ages similar to K/T event (65 Ma). Some of these basalts show an order of magni-

tude higher content of Ir (up to ~100 pg/g). These Ir levels cannot still explain the Ir enrichment observed at KTB. The major part of Ir at KTB is thus extraterrestrial and not volcanic in origin.

We have observed three limonitic layers rich in Ir in the Anjar intertrappean sediments between III and IV flow. U, Th and K measurement from this section shows a high concentration of U in these layers compared to the adjacent samples. Th/U ratio is very low in these layers (0.04 - 0.08) indicating highly anoxic conditions at the time of deposition of these layers during the K/T period.

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

### **Rb-Sr Age of Karakoram Granitoids and its Implication in Accretion Tectonics**

The Karakoram mountain range extends some 700 km from the Afghanistan-Pakistan border eastward to western Tibet along the Northwest frontiers of Pakistan and India with the Chinese province of Xinjiang. The eastern Karakoram lies to the north of the Shyok suture zone. Two distinct geological terrain could be distinguished in the eastern Karakoram; the southern terrain is dominated by granitoids and metamorphic rocks, whereas a sedimentary dominated terrain, the Karakoram Tethys, constitute the northern segment. The NW-SE trending granitoid belt exposed in the southern part of Karakoram is named as Karakoram batholith.

We have determined whole rock Rb/Sr age of eastern Karakoram leucogranite. The results show that the S-type syn-collision Karakoram plutonic phase has an age of  $83 \pm 9$  Ma with initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio of  $0.7099 \pm 0.0002$ . This suggests the presence of an older S-type granite in the Karakoram batholith. Based on geochemical data and the Rb-Sr age obtained by us, one can conclude that the oldest I-type, Jurassic-Early Cretaceous granites in the eastern Karakoram region have a pre-collision subduction related tectonic setting and the Late Cretaceous S-type granites have a syn-collision tectonic followed by the post collision S-type Miocene granites.

This work was carried out in collaboration with

(J.R.Trivedi)

### ***Zircon Geochronology of the Bundelkhand Massif, Central India***

The Bundelkhand massif in Central India is one of the Precambrian continental nuclei identified in the Indian sub-continent. It comprises primarily of various phases of granitoids which have intruded into a deformed basement comprising of gneisses, banded iron formations, metasediments, and mafic and ultramafic rocks. The massif is traversed by two prominent sets of lineaments filled with quartz veins and mafic dykes respectively. We have determined  $^{207}\text{Pb}/^{206}\text{Pb}$  ages of single zircons by an ion microprobe to delineate the geochronological evolution of this massif.

We have studied representative samples from all the major lithologies; these include five gneissic samples from different locales, all the prominent granitoid types and a sample of Rhyolite. The  $^{207}\text{Pb}/^{206}\text{Pb}$  data reveal the presence of 3.3 Ga old Archean crustal components in the Bundelkhand massif as evident from the age of enclave engulfed within gneiss and age of protolith of two of the gneissic samples. The gneisses are of three generations and were formed at ~3.3 Ga, 2.7 Ga and 2.5 Ga respectively. Large scale granitic magmatism took place at ~2.5 Ga, when different granitic and rhyolite phases were emplaced in quick succession within a time span of ~ 50 Ma. This also marks the broad stabilization of this massif. The 2.5 Ga age of stabilization of Bundelkhand massif is strikingly similar to that for the Aravalli Craton bordering the western side of the massif. This suggests a possible similarity in the temporal evolution of these two prominent Precambrian continental nuclei in the Indian Subcontinent.

This work was carried out in collaboration with Dr. K.K.Sharma of the Wadia Institute of Himalayan Geology, Dehradun.

(M.E.A.Mondal, M.P.Deomurari and J.N.Goswami)

### ***Ion Probe Determination of Rare Earth and Trace Element Abundances***

Rare earth element (REE) abundances in terrestrial and extraterrestrial samples provide very useful information on their formation and evolution history. However, the conventional neutron activation method for determining REE abundances cannot be used for microscopic samples like the refractory phases in primitive meteorites representing some of the first solar system solids. The ion microprobe is an ideal tool in such cases. The main difficulty, however, is the problem of molecular interferences which cannot be resolved even with the highest mass resolving power achievable with the ion probe. Such interferences are therefore suppressed by using the energy filtering technique in which the higher energy secondary ions from the sample are selectively chosen for analysis. The resulting ion signals at different masses of interest are then deconvoluted using analytical approach to obtain the "true" REE signal. We have now developed experimental procedures as well as analytical approaches to determine REE and trace element abundances of microscopic sample using the PRL ion probe. The relevant instrument parameters are determined using suitable REE standards. Results obtained for a set of silicate standards (NIST: SRM-610, 612 and KW3610) treated as unknown show that it is possible to measure REE abundances with a precision of better than 10% (**Fig. 5.8**), which is similar to those reported by other ion probe laboratories around the globe.

We have also determined REE and trace element abundance patterns in several hibonite grains isolated from the Murchison meteorite using this approach. These grains show REE patterns that generally reflect a nearly hundred-fold enrichment of REE abundances compared to average "solar" (CI chondrite) abundance except for the relatively less refractory REE like Eu and Yb. These patterns are similar to those found in earlier studies and confirm that the formation of the hibonite grains took place very early in the history of the solar system and that they are representative of the first 1% of the solar nebula material that have condensed to form solid objects.

The performance of the ion microprobe has also



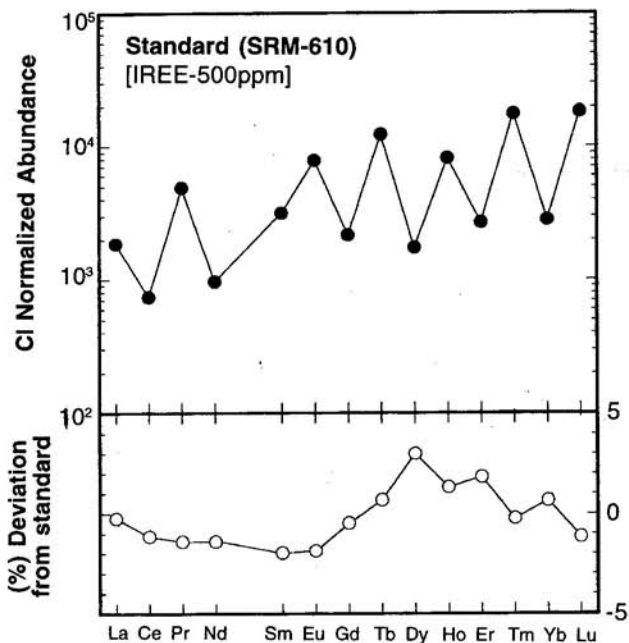


Fig. 5.8 CI normalized rare earth element (REE) abundances measured in the silicate standard SRM610. The measured abundance do not vary by more than 5% from the actual abundance (~500 ppm) for all the REE in this standard.

been enhanced by an in-house upgradation of the vacuum in the primary ion source chamber and the primary ion column. The primary ion beam density from the duoplasmatron source has increased about four times following this upgradation and the vacuum level at the primary ion source region has improved by more than an order of magnitude. Suppression of hydride interference is also clearly evident.

(S.Sahijpal, V. G. Shah and J.N.Goswami)

### Re-Os Systematics by NTIMS

The application of  $^{187}\text{Re}$ - $^{187}\text{Os}$  isotope systematics as a petrogenetic and geologic tracer are being exploited increasingly in recent years. We have upgraded the existing Rb-Sr thermal ion mass spectrometer to operate with a negative ion source and have developed chemical and analytical procedures to make precise measurements of Re-Os concentrations in environmental samples and their Os isotope composition as well. We could determine  $^{187}\text{Os}/^{186}\text{Os}$  ratios with a precision of better than 0.5% in a few tens of picogram of Os using the

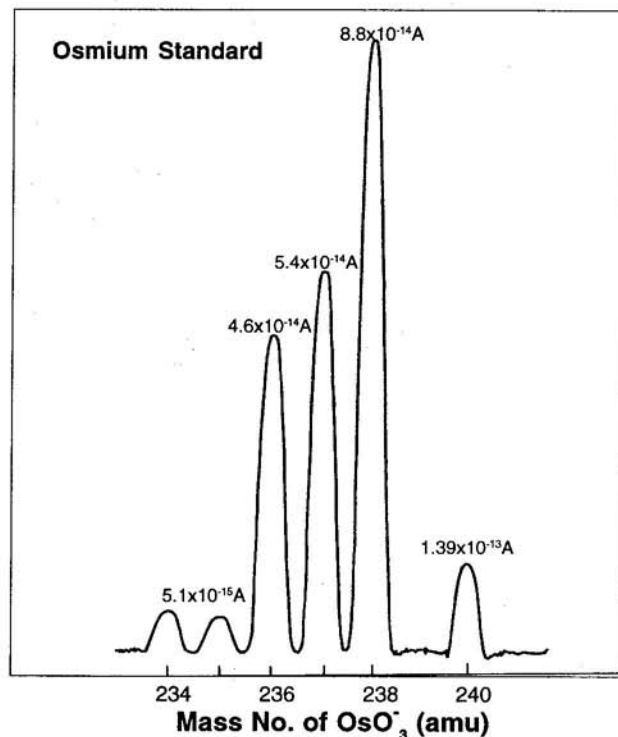


Fig. 5.9 A typical mass spectrum of osmium standard.

negative thermal ion mass spectrometry technique (NTIMS). We show in Fig. 5.9 a mass spectrum obtained for a Os standard. Typical uncertainty in the measurements of Re and Os concentrations are 1%-2% ( $\pm 2\sigma$ ). Procedural blanks for Os ranged between 0.7 to 4.2 pg and that of Re ranged from 1.7-5 pg. The  $^{187}\text{Os}/^{186}\text{Os}$  ratio have been measured with a precision of ~0.4% in sample loads of ~20 pg extracted from black shales.

This technique is currently being used for determining the chronology of black shale in the Himalaya. In addition to the study of black shales we are planning to measure the Os isotopic ratio in Deccan trap basalts and in K/T boundary samples to learn more about their sources.

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

### Isotopic Record of Vegetational Response to Monsoon Circulation in the Chinese Loess Plateau

We studied a nearly 3.5ma continuous stable carbon isotope record in the organic and inorganic fractions. The record indicates two major excursions: a marked

decrease in  $\delta^{13}\text{C}$  values, coincident with the Matuyama-Gauss magnetic boundary (2.6ma BP), and a marked increase around 0.3ma BP. Between the two periods (0.3-2.6ma BP), the  $\delta^{13}\text{C}$  values remained at about the same level. We show that our observations are quite consistent with the hypothesis that C3 plants dominated during the invariant  $\delta^{13}\text{C}$  period. Our findings also suggest reduced primary productivity during this period, presumably because the climate was then dominated by stronger winters and lower than optimum growing season temperatures required for C4 plant growth.

(D. Lal)

**Facilities  
at  
PRL**



## Electronics Laboratory

Electronics laboratory is carrying out research activities in the area of Computer Graphics, Computer Networking, Artificial Intelligence and its application in speech and vision systems. The work includes the development of dedicated hardware and software stimulation of Neural Network and Fuzzy Algorithms for real time applications like non-linear control, robotics. Some of the algorithms developed are : (i) Time series prediction, (ii) Dynamic neuron activation function, (iii) Low precision algorithm for neural network, (iv) Hand written character recognition, (v) Human face recognition and (vi) Neural network algorithm suitable for VLSI implementation etc. About fifteen under-graduate and graduate students from Engineering Colleges undertook their project in the Electronics Laboratory. They worked in the area of speech recognition, computer networking, non-linear control, pattern recognition, biological process modelling etc. The research highlights are as follows :

### **Blind Vision System**

A hand-written English character reading system is developed. The system is based on Multilayered Neural Network and Multi-Media interface. The system takes standard TIFF image fields through camera, scanner or in-built paint brush system and outputs speech corresponding to each English Capital Letter character.

### **Speech Tool Box**

A toolbox is designed to study the property of time series signals like speech. It consists of multi-media interface and data acquisition system in front-end. It consists of wave view scope, wave editing, sonogram, neural network based pattern recognition and classification features. This toolbox is used for development of speech recognition system.

## 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 of computing facility. This cluster is further connected to six X-stations and more than 150 PCs and few Work-stations distrib-

uted throughout the Laboratory. The system is also connected by a VSAT ( Very Small Aperture Terminal ) link to the INTERNET with a hub at Bangalore. Thus a full connectivity has been provided to the users for all the time from anywhere in the premises.

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 facility of making coloured slides and video tapes is there.

A 20 GB Hard Disk Drive has been installed during the year, thus making the total Hard Disk capacity as 41 GB on the IBM system. A 5 GB High Density CTD (Cartridge Tape Drive ) was also installed during the year.

The centre provides the consultations and other facilities including archival of file systems, system security, authorisation, updating the system softwares, third party softwares and public domain softwares. It also takes care of INTERNET, Ethernet and helps all the users in all respects.

## Library

### **Collection**

The PRL Library subscribes 180 scientific and technical journals.

A large number of scientific reports, data, maps etc. are also received. 262 books and 30 video cassettes were added to the Library.

### **Services**

Over 2,21,000 photocopies were made according to requests received from PRL personnel, from other Libraries and also from Research Scholars outside PRL.

Requests were received for obtaining 300 publications from other libraries on Inter-Library-Loan. Most of these publications were obtained on loan for our readers. About 280 publications were loaned by us to other libraries.

During the year 7198 books and journals were issued. Over 200 Reference Queries were answered for

providing factual information, locating addresses, giving biodata etc. About 500 queries were handled by using OPAC (Online Public Access Catalogue). Approximately 100 requests for Retrospective Search and Internet Search were undertaken.

More and more publishers are providing electronic access to full text of their journals when the paper copy is being subscribed. We have registered 24 sites of publishers for obtaining online access to either full text or table of contents of forty three journals. If need be the full text is also being downloaded occasionally. Since the URL's and the links are provided in the PRL Library Home Page, the electronic journals can easily be accessed from the Library Home Page.

As a step towards total automation, all the books, bound journals 1982 onwards, as well as the Library Member's ID Cards have been bar coded. This has made the process of loaning the documents very fast and error free.

### **Glass Blowing and Liquid Nitrogen Facility**

The glass blowing and liquid nitrogen facility caters to the need of all the experimental groups in PRL as well as several outside institutions. Some of the important jobs carried out in the glass blowing facility during the last year are Quartz-Pyre extraction bottles, distillation units, quartz sub boiling stills; vacuum flasks, glass to metal seals, fabrications of intricate glass system etc. Apart from glass jobs, brazing and soldering of vacuum components and electropolishing were carried out and gold gaskets for ultra high vacuum have been fabricated. Close to 200 jobs were carried out in this facility during the year. Apart from PRL users the service of the glass blowing facility was utilized by outside institutions like IPR, ATIRA, ONGC, NIO(Goa), Gujarat University and NGRI (Hyderabad).

During the same period, the Liquid Nitrogen facility has produced ~20,000 litres of liquid nitrogen. The facility was operating round the clock for most of the year and catered to the need of all the PRL groups including the Mt. Abu Observatory. Outside users to whom we supplied liquid nitrogen include SAC, IPR, LD Engineering Col-

lege, Sabarmati Gaushala project and several local hospitals. A number of private clinics also procured liquid nitrogen from us for uses in dermatology, cryosurgery, semen preservation etc.

### **Workshop**

With the existing facilities like machine shop, fabrication shop, painting shop and design section, the workshop at PRL gives valuable support to the experimental groups of various divisions by providing designs and fabricating sophisticated systems for the experiments. Some of the major work carried out during the year are listed below :

- The new model of Airglow Imaging system has been designed and partly fabricated. It consists of an enclosed filter wheel with eight different filter mounting by means of O ring and large washer. The wheel is driven by means of a stepper motor with reduction gear unit. The mirror mount, collimator lens housing and its focussing ring have been designed and fabricated. The instrument has been provided with MS angle structure to facilitate mounting on the observation table and also handling during transport.
- A SS304 vacuum crusher along with shock absorber stand has been fabricated by the workshop. This can crush samples in ultra high vacuum to enable analysis of gases trapped in inclusions. A magnetic hammer inside the vacuum enclosure is operated by a solenoid coil (externally placed) to crush the sample and liberate gases. This involves high accurate machining.
- Precision components like base plates and holders, cotton fibre guide, filter unit were made for fluorescence and life time experiment using laser. For fluorescence spectrometer vacuum lines were made as per the design for the reference vacuum system.
- A single system which can be used for day/night airglow measurements has been designed. This system is upgraded version of earlier day airglow

photometer and fabricated using periscope mirror arrangement with pushbull.

- A group of mechanics worked to repair IONOSONDE Antenna. This work involved debrazing and brazing the new joints at the wire junctions. All the wires from the top of 65 feet height tower were dismantled and made new. The new insulators were also fitted with wire. A electronic box from the top of the tower was brought down, repaired and fitted on top again. The repairing and fitting of all the wires were successfully completed. There is an improvement in the quality of the received signal.
- The workshop at Thaltej is deeply involved in various activities of infrared astronomy area. Few new optical instruments such as photometer, fabry perot mount, CCD mounts, spectrograph with optical fibre mount, revolving and sliding filter mount, mirror holder, lense holder, eye piece holder, P.M. tube holder were fabricated. Mounting and aligning of optical instruments and modification work on telescope dome at Mt. Abu was carried out.
- Over and above, vaccum pumps of various groups were repaired successfully. The sheet metal fabrication and structural fabrication work was also carried out as per the requirement of various users.

## Engineering Services

The Engineering Services render all technical services pertaining to civil engineering works and related building and laboratory services such as electrical, public health, air-conditioning, inter- communication system, elevators, etc. right from the land acquisition to maintenance of all buildings (residential and non-residential) and its related services for various campuses of the laboratory. The services undertaken are 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 five campuses- PRL main campus, colony Campus, Thaltej campus, Mt.Abu Campus and Udaipur Campus.

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

- Modification works in Guest House rooms for making suites and Guest House lounge interiors.
- Cement plastering to external walls of student's Hostel blocks and staff quarters.
- Cement concrete approach roads at Udaipur Campus.
- Building work of Hostel for International Students has been initiated.



**Honorary  
Fellows &  
Professors  
at PRL**

# Honorary Fellows at PRL

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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

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Professor Yash Pal

Professor S. P. Pandya

Professor R. K. Varma

Professor J. C. Parikh

Professor B. L. K. Somayajulu



**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, Kharagpur (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)
Dr D K Chakrabarty	Ion and Neutral Chemistry of Earth's Atmosphere	Ph D NPL, Delhi Univ. (1973)
Dr Harish Chandra	Ionospheric Studies and Dynamics of Middle Atmosphere	Ph D PRL, Gujarat Univ. (1970)
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)
Dr S P Gupta	Electrodynamics of Middle Atmosphere	Ph D PRL, Gujarat Univ. (1971)

Name	Specialisation	Academic Qualification
Dr R Sridharan FASc	Upper Atmospheric and Ionospheric Physics	Ph D PRL, Gujarat Univ. (1984)
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)

Name	Specialisation	Academic Qualification
Dr Sai K Iyer	Large Scale Structure, General Relativity	Ph D Washington Univ. USA (1987)
Dr Kanchan Pande	Geology, Geochronology	Ph D PRL, Gujarat Univ. (1990)
Dr Ashok K Singal	Radio Astronomy	Ph D TIFR, Bombay Univ.(1986)
Dr 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. G. Srinivasan	Cosmochemistry	Ph D PRL, MS Univ. (1995)
Dr. R. Rangarajan	Particle Physics & Cosmology	Ph D, Univ. of California, Santa Barbara (1994)
Dr. H. Mishra	Strong Interaction Physics & Nuclear Astrophysics	Ph D, Utkal Univ. (1994)