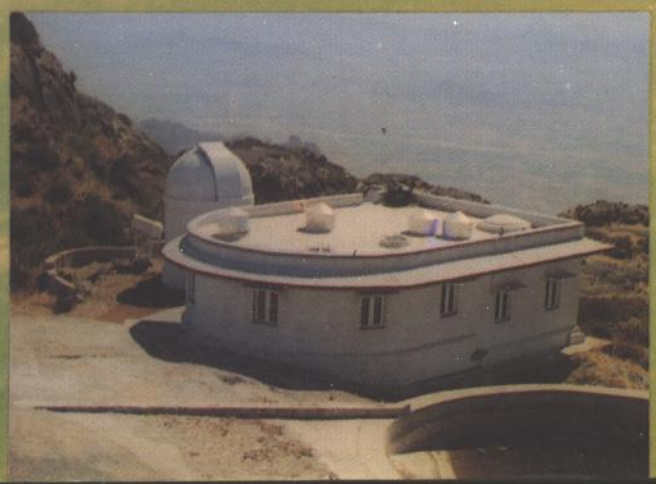
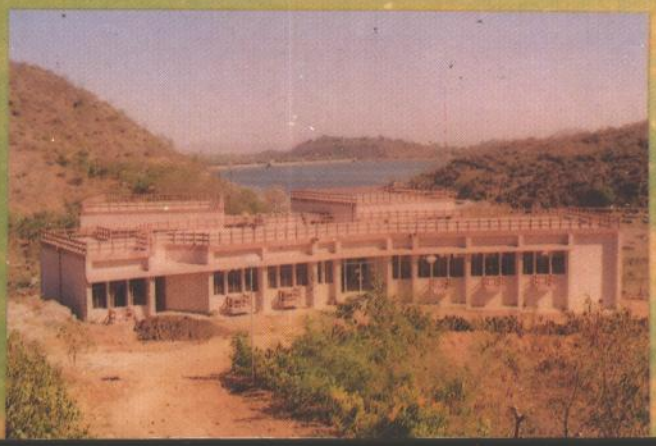
वार्षिक रिपोर्ट
1995-96
ANNUAL REPORT

भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद
PHYSICAL RESEARCH LABORATORY, AHMEDABAD





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PHYSICAL RESEARCH LABORATORY

वार्षिक रिपोर्ट
Annual Report
1995 - 96

Thaltej
Campus

PRL Main Campus

Mount Abu
Campus

Udaipur
Solar Observatory
Campus

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Contents

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Introduction

The Physical Research Laboratory is progressing with its variety of programmes in many different areas of scientific research in both macroscopic and microscopic physics. These include astronomy and astrophysics, space and solar system physics, earth and atmospheric physics in the macroscopic domain while atomic and molecular physics , nuclear and particle physics, nonlinear dynamics in microscopic domain. Some of the important achievements have been highlighted in the next section. During this year a new exciting area of research on Laser Physics and Quantum Optics has been initiated. This is a new frontier in this laboratory which throws some more challenges to the younger generation of scientists for the pursuit of scientific excellence. The composition of the theoretical physics has also been changed. A new subgroup has been formed to study nonlinear dynamics, chaos, bifurcations etc. The modelling activity has also been strengthened.

Two important astronomical events, the total solar eclipse of October 24, 1995 and the sudden appearance of Comet Hyakutake March-April, 1996 have successfully been utilized by the scientists to study Sun's atmosphere and cometary physics in more details.

A topical meeting on Particle Physics and Cosmology was organized at Mt. Abu. About forty participants from outside PRL participated in this meeting which discussed topics of current interests, namely neutrino physics, supersymmetric searches, astroparticle physics and non-perturbative QCD and confinement. The talks were meant to summarize the status of the fields and were given by experts working in respective areas.

An IGBP Workshop-cum-Brainstorming session on Atmospheric Chemistry was held at PRL to assess the current status on the atmospheric chemistry related projects presently ongoing in India at various research institutions and to formulate new coordinated programmes for the future. The meeting was attended by about forty scientists and experts from different institutions and universities.

The laboratory undertook two programmes under the Human Resource Development plan. One was an extensive course on Advanced Unix and System Administration in which about ten of our technical faculty members were acquainted with sophisticated and advanced computer systems. The other programme conducted, for the staff in administration, was on how to use computers for office automation and training in Microsoft Office was imparted. In addition, the laboratory is also extending specialized training in different activities of the laboratory to young post-graduate students under the Project Associateship program. This is in addition to the graduate and postgraduate research programmes of the laboratory for doctoral degree.

We have made considerable achievements in the front-line areas as described in the following chapters. Our work continued to be recognised by prestigious national and international awards and election to various science academies. Also the laboratory continued to exhibit strong presence at national and international scientific scene with its large number of first rate publications and invited presentations at conferences, symposia and at other academic institutions. It also continues to participate in a number of international programmes. However, we continue to work to bring the laboratory to greater heights of scientific excellence.

I take this opportunity to convey my appreciation to the PRL Council of Management for their guidance and advice. I also thank all my colleagues, administrative, technical and supporting staff for the scientific success of the laboratory.

Director

PRL in a Nutshell

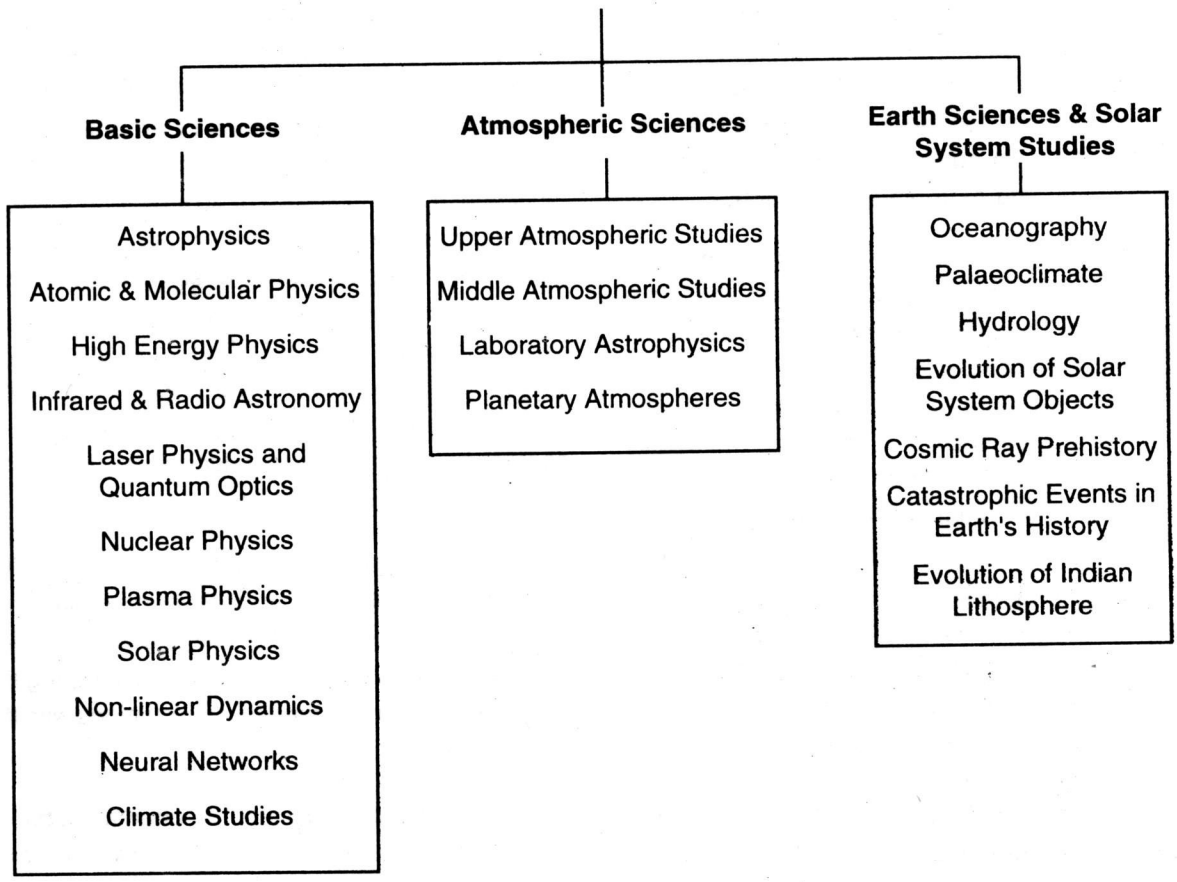
Scientific Achievements

The Physical Research Laboratory (PRL) is one of the premier research institutions of the country carrying out basic research in several areas of experimental and theoretical physics and earth sciences. Founded by Dr. Vikram A. Sarabhai soon after India's independence, in November 1947, the laboratory had its humble beginning in M.G. Science Institute. The research programs were oriented and pioneered by the scientific interests of Dr. Vikram A. Sarabhai, PRL's founder and Prof. K.R.Ramanathan, its first Director. The laboratory received recognition of the Atomic Energy Commission and became a grant-in-aid autonomous institution of the Department of Atomic Energy in 1963. With the creation of the Department of Space in 1972, PRL was transferred from the Department of Atomic Energy to the Department of Space.

In the early seventies new activities were initiated in the fields of laboratory astrophysics and plasma physics. The Geocosmophysics group which was nucleated at the Tata Institute of Fundamental Research, Bombay, moved to PRL in 1972. In the same decade, programmes in Astronomy and Astrophysics were initiated which led to the establishment of an Astronomy and Astrophysics centre at Thaltej and an Infrared Observatory at Gurushikhar. The study of Contemporary Sun is also being carried out at the Udaipur Solar Observatory, Udaipur. Recently new activities like non-linear dynamics and particle physics have been added to Theoretical Physics. Programmes on Laser Physics and Quantum Optics have also been initiated.

At present the scientific activities of the laboratory can be broadly grouped under five major divisions. They are (i) Theoretical Physics (Plasma Physics, Atomic and Molecular Physics, High Energy Physics, Nuclear Physics, Astrophysics and Climatology); (ii) Laser Physics and Quantum Optics; (iii) Astronomy and Astrophysics; (iv)

Profile of Scientific Activities



Planetary Atmospheres and Aeronomy and (v) Earth Sciences and Solar System Studies.

Astronomy and Astrophysics

The research interests of the scientists in the Astronomy and Astrophysics division cover a wide range - from the Sun through the interplanetary medium and the planetary system, to stars and the interstellar medium in our galaxy and beyond to energetic extragalactic objects at the limits of our observable universe.

The astronomy and astrophysics division of PRL operates from three campuses spread over the states of Gujarat and Rajasthan. Regular monitoring of the Sun and the study of energetic phenomena like solar flares are carried out from the Udaipur Solar Observatory (USO) located in the middle of Fatehsagar lake in Udaipur. The Gurushikhar observatory located at the highest point in the hills around Mt.Abu, houses a 1.2 m telescope and is the main centre for optical and infrared astronomical observations. These are being carried out with a variety of highly specialized instruments like infrared high speed photometers, Fabry-Perot spectrometers, optical and infrared polarimeters developed at PRL over a period of a decade and more. The Thaltej campus on the Western outskirts of Ahmedabad is the base for Astronomy and Astrophysics Division.

The year 1995-96 witnessed two important astronomical events, one totally predictable and the other totally unexpected. The total solar eclipse of October 24, 1995, though brief was a spectacular one. PRL scientists conducted Fabry-Perot Interferometric observations successfully on the elusive solar corona during the totality period lasting less than 50 seconds at Neem Ka Thana in Rajasthan. The Udaipur Solar Observatory observed the total solar eclipse from their camp at Kalpi (UP) to detect the dust rings known to exist around the Sun. The USO also undertook an ambitious project of photographing the solar corona during the total solar eclipse by a MIG - 25 flying at the height of 8000 ft with 2.5 Mach speed. The objective was to look for extended solar coronal streamers. Such an attempt has been made for the first time in the world. Another group of PRL scientists observed the totality from Lunkaransar (near Bikaner).

For the past many years there had been a dearth of really bright comets which exhibit all the cometary characteristics in full splendor such as a fiery head or coma followed by a long tenuous plasma tail and curving dust tails. This situation was greatly remedied by the sudden appearance of Comet Hyakutake (1996 B2) early 1996. This comet discovered on 30 January 1996, came within 15 million kilometer of the earth in late March 1996 on its way to perihelion. A large number of good quality photographs of the comet were taken with the Schmidt camera mounted on the drive of the 1.2 m Gurushikhar telescope. The day to day variation in the structure of the comet is clearly apparent in these photographs. Other valuable observations of the comet like infrared photometry, visual polarimetry, CCD imaging were also carried out by the scientists of the division.

The year also witnessed regular astronomical observations at Gurushikhar Observatory. A complete coverage of the light curve of the eclipsing binary star R Canis Majoris was obtained in the Infrared J and K filter bands. The analysis of the lunar occultation light curve in the infrared of the late type supergiant TV Gem has led to the detection of a circumstellar shell around the star at about 20 stellar radii. The presence of an outer shell at 500 stellar radii inferred from IRAS data alongwith the positive detection of the inner shell at 20 stellar radii suggest that irregular mass loss processes are operating in this supergiant. Imaging observations of several planetary nebula were carried out with the high resolution Imaging Fabry-Perot Spectrometer (IFPS). The analysis of the data on the interesting planetary nebula NGC 1514, whose central star is an eclipsing binary is continuing. A gradual decrease in the expansion velocity away from the central star is seen in the line profiles.

Variability studies of BL Lac object OJ 287 were continued. A multicomponent emission source in OJ 287 has been suggested. CCD imaging studies of several starburst galaxies were also carried out during the year, which also witnessed the first observations with the infrared polarimeter.

On the theoretical side, the orientation based unification scheme of powerful radio sources and quasars was

examined. Comparison of space distributions of these two types has shown a strong evidence against a unified scheme. A larger sample is being studied.

A sophisticated, state-of-the-art 1.5 million dollar Dopplergraph was installed at USO in September 1995 under the project, Global Oscillations Network Group (GONG), for a near-continuous 24-hour solar coverage. The aim of this instrument is to accurately obtain the modal frequencies of solar oscillations and to probe the sun's interior using the recently developed tool of helioseismology.

Theoretical Physics

Searching for signals beyond the standard electroweak model has been one of the activities of the group. A specific study carried out during this year concentrated on the signatures of lepton number violating interactions present in the supersymmetric version of the standard model. These interactions which are expected to be generated due to quantized gravity can lead to the decay of the dark matter supersymmetric particles present in the universe into positrons which can be experimentally looked for. The present constraints on these interactions were systematically analyzed.

With the existence of the top quark firmly established, it is appropriate now to study the non-standard interactions of top quark. One such study made this year concentrated on various types of asymmetries in the decays of the top anti-top pairs to charged leptons. It was argued that this may provide a viable way for looking into CP violating interactions of top quark to the ZBoson and the photon.

Significant insight into the vacuum structure of the Quantum Chromodynamics (QCD) was obtained. A variation ansatz for the vacuum structure proposed earlier was modified by including irreducible four point condensate into the ansatz. This resulted in a significant improvement in the description of the hadronic properties, particularly in the pseudo-scalar channel.

The equilibrium structure of a pressure suported thick plasma disk around a compact object with self-consistent electromagnetic field has been obtained both in the Newtonian and general relativistic framework bearing out the important contribution of the relativistic formalism which introduces certain constraints. Concerning the study of the effect of centrifugal force reversal on the shape of collapsing fluid configuration, analysis has been made for the case of a slowly rotating configuration which shows the attainment of ellipticity maximum for configurations with radius smaller than the one obtained for the case without rotation. On the gravitational wave front, the results accomplished are in the realm of wave generation in general binary systems for a class of different gauges (in 2 post-Newtonian order) and the propagation of waves in a perfect fluid medium, wherein the transport of the secondary amplitudes does indicate a possible interaction between the waves and the medium.

In the realm of atomic and molecular physics a simple but new method has been developed to prove addition theorems for Solid Harmonics and the second Born amplitudes which gives new insight into the richness of the contents of the expansion of plane waves in terms of a complete set of spherical harmonics.

The newly formed subgroup of computational physics has devoted its efforts in several interesting analysis of classical and quantum chaos. Using quantum maps the accuracy of the semiclassical trace formula has been studied and evaluating certain incomplete Gauss sums exactly, a first example has been provided of a quantised chaotic system whose trace is not the semiclassical trace. Further, studying the local scaling properties associated with straight line periodic orbits in Hamiltonian systems, a strong evidence of local scaling of the Poincaré section has been shown, with exponents depending simply on the degree of homogeneity of the potential.

Laser Physics and Quantum Optics

The work in this newly established division has been primarily theoretical though considerable collaborative work was done with experimentalists round the globe. On the theoretical side some of the important contributions consist of development of a general approach to the coherent and squeezed states of SU(1,1); utilization of

whispering gallery modes for enhancement of cavity QED effects; possibility of the production of sub Doppler resolution; development of models for dicode laser spectroscopy; atomic correlation induced spectral changes; coherent population trapping in dense systems; quantum dynamics of nonlinear optical systems. Collaboration with experimental groups led to the observation of two photon decay of Rydberg atoms (MPI, Garching); observation of quantum noise effects in coherently pumped amplifiers (Rochester) ; modelling of the experiments on nonliniar magneto optical effect (Imperial college). Modelling of the Florance experiments on Electromagnetic field induced transparancy under radiation trapping condition has also been initiated.

Planetary Atmospheres and Aeronomy

The research interests of Planetary Atmosphere and Aeronomy Division cover a wide range of physical and chemical processes that occur in the Earth's atmosphere and as well as other planetary and cometary atmospheres. The investigations are mainly based on experimental activities with a modest attempt in atmospheric modelling and numerical simulations. Balloon, cruise and rocket-borne measurements of atmospheric parameters alongwith the remote sensing of the atmosphere by means of optical and radio sounding techniques and laboratory simulation studies have been conducted.

The research programs of the division cover studies in upper atmosphere, middle atmosphere, planetary and cometary atmospheres and laboratory astrophysics.

In the upper atmospheric studies, a proxy indicator for the changes occurring around the plasma pause region was obtained in terms of daytime auroral emissions by operating a multi-wavelength dayglow photometer from Maitri during January - February 1995.

Intricate wave like features associated with the crest of the equatorial ionization anomaly are identified by operating the dayglow photometer from low latitude region.

Optical aeronomy laboratory at Gurushikhar was commissioned and a number of sophisticated optical photometers and high resolution spectrometers are being operated regularly to study thermosphere-ionosphere system at low latitudes in line with the I-STEP program.

Further success is achieved in the field of optical aeronomy with a daytime Fabry-Perot spectrometer, first of its kind, having been developed at PRL. Round the clock measurements of neutral winds and temperatures in thermosphere/mesosphere will be possible now.

The generation of the plasma density irregularities in the lower F-region is explained using nonlinear numerical simulation model and the results obtained from Ionization Hole rocket campaign. Penetration of the fringe fields associated with the plasma bubble at the base of the F-layer is found to be important in their generation.

Detailed investigation of geomagnetic data acquired during IGY-IGC period revealed that the horizontal component of the magnetic field variations during nighttime over Huancayo could be accounted for by the changes in the ionospheric electric field. Evidences of significant electric fields in the E-region over Thumba is also obtained by reexamining the results obtained in the earlier rocket flights.

As part of the campaign for studying the atmospheric effects of the total solar eclipse on 24th October, 1995, several experiments were conducted. Total columnar measurements of ozone over Ahmedabad showed oscillations following the eclipse. Mesospheric and thermospheric dayglow measurements made over Mt. Abu also showed wave activity triggered in the atmosphere and their upward/ horizontal movement. Decreases in the ionospheric electron densities over Ahmedabad with slight indication of wave activity were also observed using radio sounding technique.

In the cometary atmospheric studies, modelling studies suggest that the unexpectedly abundant C^+ ion as observed by the Giotto mission can be explained with the inclusion of the production of carbon bearing ions by the auroral electron precipitation of solar wind origin as one of the possible sources.

In the middle atmospheric studies, as a part of the Indian JGOFS (Joint Global Ocean Flux Study) program, measurements of N_2O and CH_4 in air and in the water column in the Arabian sea were initiated in 1994. A ship cruise was undertaken during July-August 1995 to study the fluxes of these gases during the monsoon period when high up- welling prevails in the Arabian sea.

The Nd-YAG Lidar was moved to Gurushikhar and a new 90 cm telescope was installed. The new set up extends the lidar observations upto 70-80km for the measurements of the temperature structure and gravity wave features from density perturbations in the altitude region of 30-80km. Multiwavelength measurements on the vertical distribution of the aerosols in the altitude region below 30km are being continued.

As a preparatory phase of the Indian Ocean Experiment (INDOEX), a multi-national scientific program, to study the aerosol-clouds chemistry-climate interactions, a ship cruise was undertaken. Experiments carried out by PRL scientists include : multi-wavelength Sun photometers for spectral variation of aerosol optical depth, impactor measurements of the aerosol size distribution and the pyroheliometer measurements of the incoming solar radiation intensities. Spatial and temporal variations of ozone concentration along with other chemically and radiatively active minor constituents such as oxides of nitrogen, methane and carbon monoxide were also measured.

Modelling studies of stratospheric ions over mid latitude region revealed $H^+.(CH_3CO_3H_2O$, $NO_3(HNO_3)_2$ and $H^+(H_2O)_3$, $H^+(H_2O)_4$, CO_3^-, HCO_3^- to be the dominant ions at 20 and 45 km altitudes respectively.

In Laboratory Astrophysics group, the research activities during the last one year include the measurement of total electron scattering cross section of carbon dioxide at low electron energies (0.91-9.14 eV), and the study of temperature dependence of photoabsorption cross sections of sulphur dioxide in the incident photon wavelength region from 180-320 nm. Another activity has recently been started in the laboratory to measure radiative life times of the molecules using laser beam and the work on NO_2 has been initiated. All the above three activities would be continued in near future on different molecular systems of aeronomic and astrophysical interests.

Earth Sciences and Solar System Studies

The two Areas, Oceanography and Climate Studies (OCE-CS) and Solar System and Geochronology (SOS-GE) of this Division continue to pursue programs in ocean circulation, palaeoclimates, evolution of the solar system objects and of the Indian lithosphere and catastrophic events in Earth's history.

Our efforts to decipher the climatic and environmental history of the Indian subcontinent and adjacent regions through multiproxy mapping of continental and marine archives continued. As a part of this programme, we have been studying the formation and spread of deserts in and around India and their relation to palaeomonsoon. In this context, the first event - chronostratigraphy of the Oman and Rub An Khali deserts was established through luminescence dating. The results show that the aeolianites deposition took place between 229ka and 112ka BP and Oman desert ~120ka old.

Investigations on the evolution of Nal Sarovar and the retrieval of palaeoenvironmental information stored in its sediments were completed. Based on remote sensing, sedimentological, mineralogical, isotopic and geochronological studies a three stage evolution for the Nal Sarovar during the past ~ 120ka has been suggested. The chemical and isotopic composition of organic matter of these sediments yield records of climate which broadly agree with those reported from the Rajasthan Lakes.

Stable isotopic studies of carbonatite samples from Amba Dongar, Gujarat have indicated two generations of calciocarbonatites with distinct initial carbon isotopic compositions indicating mantle heterogeneity.

In oceanography, our studies on the water circulation characteristics of the Arabian Sea and air-sea exchange of CO_2 were continued. Towards these ^{14}C measurements of atmospheric CO_2 and Arabian Sea waters were made during 1993-95. The atmospheric CO_2 has a $\Delta^{14}C$ value of 115±5‰ which in conjunction with earlier reported measurements in the northern hemisphere yields

a mean life of 15 years for the residence time of ^{14}C in atmosphere.

With a view to assess the role of atmospheric deposition of nutrients in contributing to "new production" in the oceans, we have measured the atmospheric supply of NO_3 (a limiting nutrient for biological productivity in the oceans) to the surface waters of the north eastern Arabian Sea as a part of the national Joint Global Ocean Flux Study programme. The NO_3 concentration in the marine aerosols range between 4 to 66 $\mu m/10^3 m^3$ and show a strong correlation with ^{210}Pb suggestive of continental source for NO_3. The deposition flux of NO_3 to the surface waters is estimated to be ~ $20 \mu mm^{-2} d^{-1}$, only a few percent of that supplied via upwelling.

In terms of major instrumentation, an Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) was procured during the year. The instrument has been set up and calibrated for the measurement of several major elements in geological and environmental samples.

A study of cosmic ray produced ^{44}Ti activity in a selected set of meteorites that fell during the last century indicate that the heliospheric magnetic field was weaker during the Gleissberg minimum and the GCR intensity was high by ~ 50-100% during this period. This enhancement is much higher than predicted on the basis of variation in sun-spot numbers.

Studies of noble gas records in the Efremovka meteorite suggest the presence of the short-lived nuclide ^{36}Cl (= 0.43 Ma) in the early solar system. This is the first report of the presence of ^{36}Cl in meteorite and compliments our earlier observation of ^{41}Ca (= 0.15 Ma) in Efremovka. This result tightly constraints the time scale for the formation of some of the first grains in the solar system to ~ 1 Ma.

Continued geochronological studies of samples from the Deccan province showed that the dykes, which may have fed the lava flows, span in age from 62-68 Ma, consistent with the ages of the lava flows. Analysis of the available geochronological data for Deccan samples show that the major pulse of Deccan volcanism predates both K/T boundary event and the 29R chron.

A geochronological framework for the Singhbhum Craton has been established from single zircon $^{207}Pb/^{206}Pb$ dating by the ionmicroprobe. The oldest crustal component has an age of 3.6 and the stablization of this craton took place as early as 3.1 Ga.

RESEARCH FACILITIES AVAILABLE

Major Equipments

Infrared Telescope at Mt. Abu

Solar Telescopes, Video Magnetograph and Dopplergraph Telescope at Udaipur Solar Observatory

Radio Telescope at Thaltej near Ahmedabad

Radio Telecope at Rajkot

Lidar

Gas Chromatographs

Dobson Spectrophotometer

Digital Ionosonde

Day-Glow Photometer

Multiwavelength Daytime Auroral Photometer

Scanning Fabry-Perot Interferometer

Doppler Imaging Spectrometer

All Sky Imaging Camera

UV Photoelectron Spectrometer

Excimer Laser

Ion Probe

Radiation Detectors

Luminescence Dating Spectrometer

Atomic Absorption Spectrophotometer

Ion Chromatograph

Spinner Magnetometer

Inductively Coupled Plasma Emission Spectrophotometer (ICP-AES)

Stable Isotope Mass Spectrometer

Rb-Sr Mass Spectrometer

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 disks. 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, 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.

No. of Ph.D Students	50
No. of Post Doctoral Fellows	18
No. of Project Scientists	2
No. of Project Associates	5

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.

No. of M.Sc. students for summer training 18

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.

No. of students taken

(i) computer science and application	4
(ii) engineering	25
(iii) diploma	8

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

No. of personnels trained in

(i) computer centre	4
(ii) electronics laboratory	8
(iii) library	4
(iv) maintenance	3
(v) workshop	12
(vi) administrative services	3

RESEARCH AND OTHER SCIENTIFIC DETAILS

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

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

Theses submitted	8
Papers published in journals	
(a) national	18
(b) international	97
Papers published in proceedings	23

Books/Journals edited

Kota, V. K. B. and Devi, Y. D., Nuclear Shell Model and the Interacting Boson Model : Lecture Notes for Practitioners, published by IUC- DAEF, Calcutta(1996).

D.K. Chakrabarty was one of the editors of the Journal (1994-96) "Advance in Space Research", (Pergamon), Vol. 17, No. 11, 1996.

Papers presented in symposia and schools etc.	
(a) National	71
(b) International	45
Invited/Review talks given	36

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. In the reporting year we have convened the following:

1. A Topical Meeting on Particle Physics and Cosmology was held at Mt. Abu during October 10-14, 1995 (convener - S.B.Khadkikar, A.Joshipura and S. Mohanty).

2. DST-ISRO Workshop on Total Solar Eclipse of October 24, 1995 was held at USO, Udaipur on September 28-29, 1995 (convener - A. Bhatnagar).

3. A DST sponsored two day session on the Thrust Areas in Lasers, Optics, Atomic and Molecular Physics was held in October 1995 (convener - G.S. Agarwal).

4. A one day Workshop-cum-Brain Storming Session on Atomospheric Chemistry and Global Change Studies was held on August 8, 1995 at the Physical Research Laboratory (convener - A. Jayaraman).

5. An Inter Centre Seminar in Hindi on Space Science in the Twenty First Centruy was held in PRL during 23-25 January, 1996 (convener - R.N. Mishra).

6. Symposium on Satellite based Atmospheric Research and Communication (IMSA-SARC 95), Physical Research Laboratory, Ahmedabad, December 25, 1995 (co-convener - S.P. Gupta).

Dr. Rajmal Jain was invited as a resource person for telescope making at the International Workshop on SAARC Astronomy Program organised by Bal Bhawan, New Delhi during October 7 - 27, 1995.

DISTINGUISHED VISITORS AT PRL

Prof. Virendra Singh, Director, Tata Institute of Fundamental Research, Bombay visited PRL and delivered the Seventh Ramanathan Memorial Lecture on The Importance of Being Contextual in Quantum Mechanics.

Dr.Bulusu Lakshmana Deekshatulu, Director, National Remote Sensing Agency, Hyderabad visited PRL and delivered the Eighth Ramanathan Momorial Lecture on Computer Image Processing-A Brief Review.

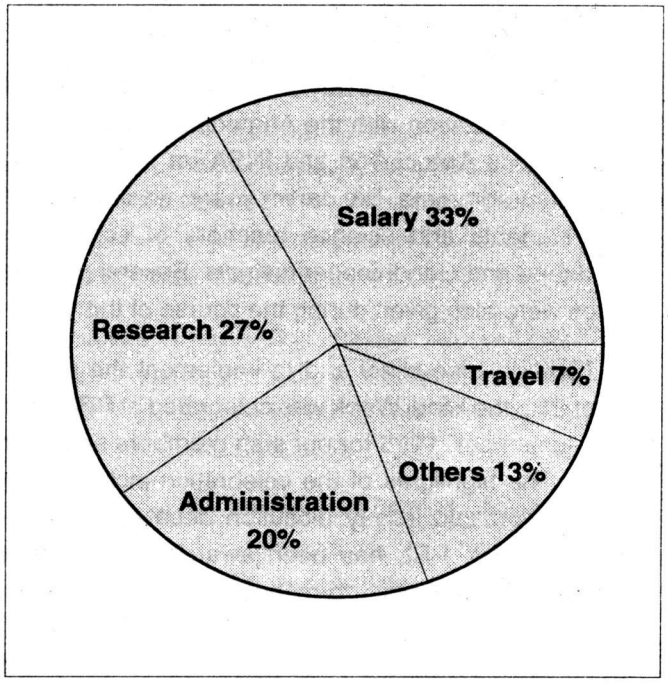
Prof. T. Mossberg visited PRL under INDO-US program. Other distinguished visitors to PRL include Prof. D. Lal, Prof. Namiki, Prof. M. L. Mehta, Prof. V. K. Gaur Prof. J. P. Conerade, Prof. D. D. Bhawalkar, Prof. J. C. Bhattacharya, Prof. D. Lambert and Prof. Roberto Galino.

SEMINARS AND COLLOQUIA HELD

The laboratory has an extensive seminar and colloquium programme. Reputed sceintists, both from national and international institutions are invited to give seminars and colloquia. The following gives an idea of the seminar and colloquium programmes at PRL:

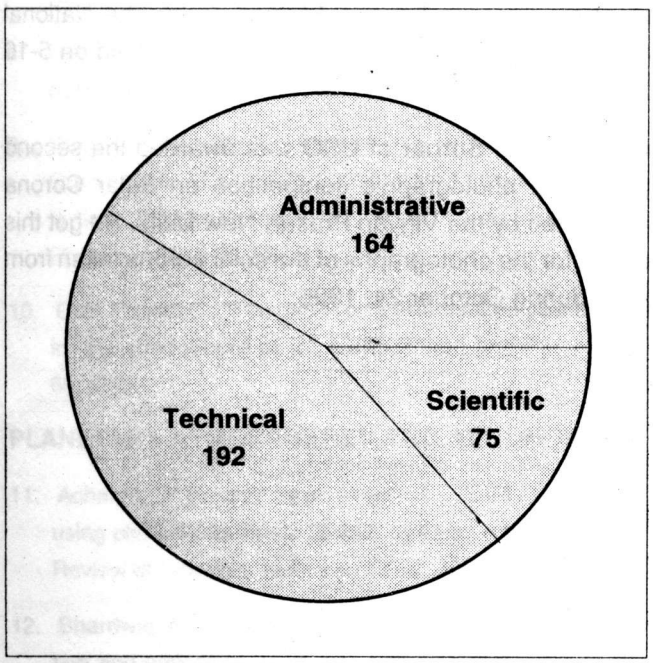
Seminars held	108
Colloquia held	30

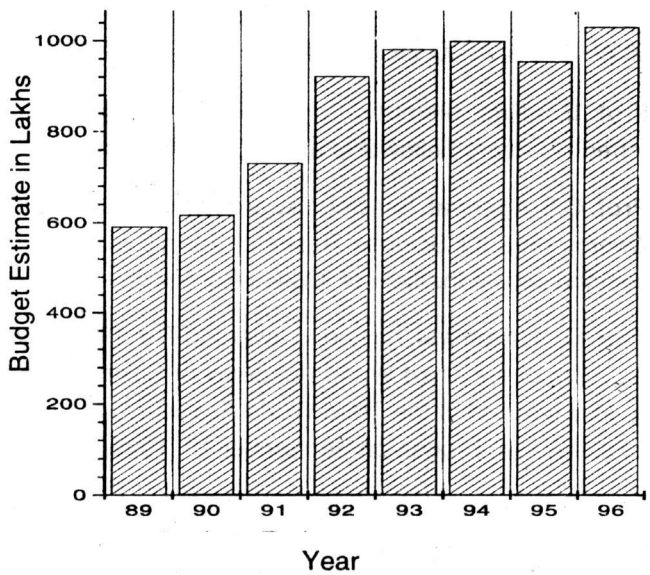
About 50% of seminars and coloquia were delivered by visitors from within and outside the country.



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 Mount Abu. The staff structure and the details of budget are shown in the above figures.





MISCELLANEOUS

The National Science Day Celebration was organised at PRL in association with the Ahmedabad Chapters of Indian Physics Association and INSA on February 24, 1996. The programme, like earlier years, was dedicated to the students and science teachers of schools in Ahmedabad and Gandhinagar districts. Several popular lectures were also given during the course of the year.

To popularise Hindi and to implement the use of Hindi at PRL the Hindi Week was celebrated at PRL from 11-17 September, 1995 for our staff members and their families. The highlights of the celebration included the traditional word quiz, essay, elocution, debate and recitation competition. PRL has been awarded the **Visesh Puraskar** for excellent performance in implementing Official Language during 1994-95.

PRL also publishes a scientific popular newsletter PRL News which contains informative science articles. These publications are distributed to universities, scientific institutions, embassies and public enterprises.

AWARDS AND HONOURS

Prof. U.R.Rao, Member, Space Commission was conferred Honorary Fellowship at PRL.

Prof. G.S.Agarwal, has been awarded the fifth G.D.Birla Award, 1995 for Science Research for his outstanding contributions in the field of Optics Research.

Prof. G. S. Agarwal, has been awarded The 1994 Physics Prize of the Third World Academy of Sciences at a special function of the Third World Academy of Science held at Abuja, Nigeria on September 18, 1995.

Prof. G.S.Agarwal, has been invited to be a Honorary Professor of the Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore for a period of five years.

Prof. R.Sridharan, has been elected Fellow of the Indian Academy of Sciences, Bangalore.

Dr. Anjan Joshipura, has been elected Fellow of the Indian Academy of Sciences, Bangalore.

Dr. N.N.Rao of the Theoretical Physics Division has been awarded Shri Hari Om Ashram Prerit Dr. Vikram Sarabhai Award for the year 1995.

Dr. S.K.Gupta, has been elected a Fellow of the Gujarat Science Academy.

Dr. C. Debi Prasad was awarded the Distinguished Membership of Alumni of Kurukshetra University. The award was presented to him by the Governor of Haryana Shri Mahavir Prasad on January 11, 1996.

Dr. C. Debi Prasad was elected regular member of the International Astronomical Union (IAU).

Shri H.S. Mazumdar was awarded the "Pride of Ahmedabad 1996" by Medical Association of Ahmedabad.

One of the papers "High resolution 2-dimensions maps of 630.0nm Dayglow Emission from Equatorial Latitudes - First Results" authored by **D.Pallam Raju and R.Sridharan** was adjudged as the best contributed paper under the themes of Ionosphere- Thermosphere - Magnetosphere Satellite Beacon Studies during the National Space Science Symposium at Hyderabad held on 5-10 February, 1996.

Mr. Laxmilal Suthar of USO was awarded the second prize in a photographic competition on Solar Corona conducted by the Vigyan Prasar, New Delhi. He got this award for the photographs of the solar corona taken from Agra during October 24, 1995.

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17. Lakshminarayan, A. and Sheorey, V.B., "Quantum chaos in maps and in smooth bounded systems", Advances in Theoretical Physics, ed. A.P. Pathak, Narosa, New Delhi (1996).

Particle Physics

18. Rindani, S.D., "CP-violation at colliders", Proceedings of the Third Workshop on High Energy Particle Physics, Madras, 1994, Pramana - Journal of Physics Suppl., **45**, 263 (1995).

19. Joshipura, A.S., "Neutrino oscillations : Theory versus experiments", Proceedings of the Workshop on High Energy Physics Phenomenology, WHEPP, Pramana, **45** (1995) 173.

Nuclear Physics

20. Khadkikar, S.B., Pandya, S.P., Praharaj C.R. and Rath, A.K., "Low energy spectra of rare earth nuclei and nuclear moment of inertia", International Nuclear Physics Symposium (INPS-95), B.A.R.C., Bombay, organized by D.O.E. India, **A45** (1995).

21. Vinodkumar, P.C., Garg, Dimple, Bannur, V.M. and Khadkikar, S.B.,"Hadronic masses using relativistic harmonic confinement model", International Nuclear Physics Symposium (INPS-95), B.A.R.C., Bombay, organized by D.O.E. India **E04**, (1995).

22. Vinodkumar, P.C., Bannur, V.M. and Khadkikar, S.B., "Hadronic masses in the open flavours from relativistic harmonic confinement model ", Proceedings of the International Nuclear Physics Conference, August 21-26,1995 Beijing, China,3 (1995).

23. Kota, V.K.B., "Nuclear spectroscopy in large shell model spaces : Recent advances", Nuclear Structure Physics II, eds. S.N. Chintalapudi and A.K. Jain (IUC-DAEF publication, Calcutta, (1996) 92.

Theses Submitted During 1995-96

1. **Mehta M. P.**

   Some investigation in time dependent canonical perturbation theory (December 1995)

2. **Pallam Raju D.**

   Studies of daytime upper atmosphere phenomena using ground based optical techniques (March 1996)

3. **Prahalad V.**

   Photoabsorption studies of molecules at different temperatures (February 1996)

4. **Ramachandran S.**

   Aerosols in the tropical middle atmosphere (November 1995)

5. **Ragland S.**

   Photometric studies in infrared astronomy (February 1996)

6. **Sheel Varun**

   Vacuum structure in QCD & Hadronic correlators (January 1996)

7. **Someshwar Rao**

   Studies on physical basis of luminescence geochronology & its applications (February 1996)

8. **Yadav D.**

   Chemical & isotopic studies in coastal areas of the Arabian Sea & Saline lakes of Rajasthan, India (June 1995).

Papers Presented in Symposia/Schools in 1995-96

INVITED PAPERS/LECTURES

ASTRONOMY ASTROPHYSICS

1. "Binary Star Studies using Small Telescope" at the IUCAA Workshop on Instrumentation for Small Telescopes and Astronomy Programmes at University Level, at K.V.Parekh Science College (Bhavnagar University), Mahuva, February 26-March 1,1996 by **N.M. Ashok**.

2. "Occultation Phenomenon in Astronomy" at the IUCAA Workshop on Instrumentation for Small Telescopes and Astronomy Programmes at University Level, at KV Parekh Science College (Bhavnagar University), Mahuva, February 26-March 1,1996 by **T.Chandrasekhar**.

3. "Fabry-Perot Interferometry in Astrophysics" at XVII Annual meeting of the Astronomical Society of India, Guwahati, January 17-20, 1996 by **J.N. Desai**.

4. "Atmospheric Seeing - Its Importance for Astronomical Imaging", at the IUCAA workshop on Instrumentation for Small Telescopes and Astronomy Programmes at University Level, at K.V.Parekh Science College (Bhavnagar University), Mahuva, February 1996 by **J.N. Desai**.

PLANETARY ATMOSPHERES AND AERONOMY

5. "Optical Studies of the Equatorial Ionosphere-Theremosphere System" at the XXI General Assembly of the International Union of Geodesy and Geophysics, Boulder, U.S.A., July 2-14, 1995 by **R. Sridharan.**

6. "Suspended Particulate Matter in the Atmosphere and their Consequences" at the One Day Seminar on Environment and Health, Botany Department, Gujarat University, Ahmedabad, September 1, 1995 by **A. Jayaraman.**

7. "Remote sensing of atmospheric aerosols from space" at the Training School on Satellite Meteorology, Techniques and Applications, Space Applications Centre, Ahmedabad, November 13 - December 8, 1995 by **A. Jayaraman.**

8. Series of five lectures on

   (a) Interaction of Light with Matter : Introduction

   (b) Instruments and Methods in Photoabsorption Spectroscopy - I

   (c) Instruments and Methods in Photoabsorption Spectroscopy - II

   (d) Photoabsorption and Photoionisation of Atoms and Molecules

   (e) Photoelectron Spectroscopy and Angular Distributions of Photoelectrons and Fluorescence Spectroscopy of Molcules by Photon Impact at the Third SERC School on Atomic and Molecular Physics, CAT., Indore, December 11-29, 1995 by **Vijay Kumar.**

9. "Lidar Probing of the Atmosphere - Recent Trends" at the National Laser Symposium - 96, Bhabha Atomic Research Centre, Bombay, January 17-19, 1996 by **A. Jayaraman.**

10. "Thermospheric Phenomena Relevant for I-STEP Studies" at the I-STEP Workshop, Osmania University, Hyderabad, February 5, 1996 by **R. Sridharan.**

EARTH SCIENCES AND SOLAR SYSTEM STUDIES

Oceanography and Climate Studies

11. "Palaeoenvironmental Record from Thar Desert", at the Symposium on Palaeomonsoon in the Old World Desert Belt since 135 Ka, INQUA, August 13, 1995 by **A.K. Singhvi.**

12 "Role of Atmospheric Deposition on Marine Chemistry, Biology and Sedimentation" at the Sixth Conference on IASTA, Physical Research Laboratory, Ahmedabad, November 28-30, 1995 by **S. Krishnaswami.**

13. "Chronology and Palaeoenvironmental Significance of Quaternary Desert Sediments in SE Arabia" at the International Conference on Quaternary Deserts and Climatic change, Al Ain. United Arab Emirates, December 9-11,1995 by **A.K. Singhvi.**

Solar System & Geochronology

14. "Studies of Low Energy Cosmic Rays from Space" at the National Space Science Symposium held at Osmania University, Hyderabad, 6-10 February (1996) by **J.N. Goswami.**

THEORETICAL PHYSICS

Plasma Physics

15. "Recent Developments in Ionospheric Modification Experiments", in the Autumn College on Plasma Physics, at the International Centre for Theoretical Physics, Trieste, Italy, September 18 - October 13, 1995 by **N.N. Rao.**

16. "Low-frequency Waves in Magnetized Dustry Plasmas", in the Autumn College on Plasma Physics, at the International Centre for Theoretical Physics, Trieste, Italy, September 18 - October 13, 1995 by **N.N. Rao**

17. "Solar-wind-magnetosphere Models", at the National ISTEP Workshop, Osmania University, Hyderabad, February 5, 1996 by **A.C. Das.**

18. "Ionosphere-Magnetosphere Coupling", at the 9th National Space Science Symposium, NSSS-96, Osmania University, Hyderabad, February 6-10, 1996 by **A.C. Das.**

Nonlinear Dynamics

19. "Detection of a Class of Localized States in a Chaotic quantum Systems, in the Adriatico Research Conference on Information Theory in Classical and Quantum PHysics", at the International Centre for Theoretical Physics, Trieste, Italy, August 29 - September 1, 1995 by **V.B. Sheorey**

Particle Physics

20. "Models of Neutrino Masses", in the Workshop on High Energy Physics Phenomenology, Calcutta, January, 1996 by **A.S. Joshipura.**

21. "Astrophysical Constraints on Violation of Equivalence Principle in Gravity", at IAGRG Conference, Institute of Mathematical Sciences, Madras, February 15-17, 1996 by **Subhendra Mohanty.**

Nuclear Physics

22. "New Signature for g-bosons in the Magnetic Dipole Strength Distribution of Deformed Odd Mass Nuclei" at the International Sympsoium on The Structure of Medium-Heavy Nuclei, RIKEN, Japan, December 26-27, 1995 by **Y.D.Devi,** and V.K.B. Kota.

23. "Spectral Averaging Theory for Nuclear Level Densities: Some Tests and Systematic Analysis of fp-shell" at the Workshop on Nuclear Structure Physics (III), M.S. University, Tirunelveli, January 29 - February 2, 1996 by **D. Majumdar,** and V.K.B. Kota.

24. "New Applications of the SU(3) Dynamical Symmetry of Interacting Boson Model", at the XIX Inernational Symposium on Nuclear Physics, Oaxtepec, Mexico, January 3-6, 1996 by **V.K.B. Kota.**

Atomic and Molecular Physics

25. "Ionisation and Electron Capture in Relativistic Ion - atom Collision", at the Discussion Meeting on Ion-Atom and Ion-Molecule Collision Phenomena, at the Tata Institute of Fundamental Research, January 29-31, 1996 by **D.P. Dewangan.**

26. "Electron - positron Pair Production in Relativistic Ion - atom Collision" at the Discussion Meeting on Ion-Atom and Ion-Molecule Collision Phenomena, at the Tata Institute of Fundamental Research, January 29-31, 1996 by **D.P. Dewangan.**

LASER PHYSICS AND QUANTUM OPTICS

27. "Microscopic Theory of Correlation-induced Shifts of Spertral Lines", in the Seventh Rochester Conference on Coherence and Quantum Optics, at Rochester,by **G. S. Agarwal.**

28. "Electromagnetic Field-induced Control of Optical Properties and Quantum Optic", in the Meeting of the Third World Academy of Sciences Abuja, by **G.S. Agarwal.**

29. "Enchancing Nonlinearities for Spectroscopic Applications", in the International Conference on Spectroscopy, BARC, Bombay,by **G.S. Agarwal.**

30. "Controlling Light by Light-induced Atomic Nonlinearities", in the Indian Nation Science Academy (INSA) Symposium on Nonlinear Phenomena, Amritsar,by **G.S. Agarwal.**

31. "Coherent Population Trapping-Theory and Applications" in the SERC School in Atomic and Molecular Physics, Indore,by **G.S. Agarwal.**

32. "Inhibition and Enhancement of Spontaneous Emission" in the SERC School in Atomic and Molecular Physics, Indore, by **G.S. Agarwal.**

CONTRIBUTED PAPERS

ASTRONOMY ASTROPHYSICS

1. "CCD Imaging of Impact Sites on Jupiter during the Period of Collision with Comet Shoemaker Levy 9 - Observations at Jaisalmar" at XVII Annual meeting of the Astronomical Society of India, Guwahati, January 17- 20, 1996 by Anandmayee Tej, T.Chandrasekhar, N.M.Ashok, Sam Ragland, S.N.Mathur and Jinesh Jain.

2. "Simultaneous Observations of Large Enhancement in the Flux of PSR 0950+08 over a 200 km Baseline at 103 MHz" at IAU Colloquium 160 on Pulsars : Problems and Progress, University of Sydney, Australia, January 8-12, 1996 by Bobra A.D., Harish Chandra, H.O.Vats, P.Janardhan, G.D.Vyas and M.R.Deshpande.

3. "Detection of Circumstellar Dust Shell around Supergiant TV Gem from Milliarcsecond Resolution Near Infrared Observations" at XVII Annual meeting of the Astronomical Society of India, Guwahati, January 17-20, 1996 by Chandrasekhar, T, Sam Ragland, N.M.Ashok

4. "Surface Photometry of Markarian Galaxies M35 and Mrk 779" at The East Asia Meeting of Ground Based Astronomy, Tokyo, Japan, July 17-22, 1995 by U.C. Joshi and Aparna Chitre.

5. "An Infrared Polarimeter for Astrophysical Study" at The East Asia Meeting of Ground Based Astronomy, Tokyo, Japan, July 17-22, 1995 by Joshi, U.C., K.S.B.Manian, Vishal Shah, J.S.Chauhan and Aparna Chitre.

6. "Multicolor Surface Photometry of Galaxies : Mrk 35 and Mrk 799" at XVII Annual meeting of the Astronomical Society of India, Guwahati, January 17-20, 1996 by Joshi, U.C. Aparna Chitre, U.C.Joshi and J.B.Srivastava.

7. "Near Infrared Polarimeter for Astrophysical Study" at XVII Annual meeting of the Astronomical Society of India, Guwahati, January 17-20, 1996 by Joshi, U.C., K.S.B.Manian, J.S.Chauhan, Vishal Shah, Aparna Chitre, Shashikiran Ganesh and M.R.Deshpande.

8. "Ultra Short Time Variability in BL Lac Object OJ 287" at XVII Annual meeting of the Astronomical Society of India, Guwahati, January 17-20, 1996 by Joshi, U.C.,

9. "IPS Observations of the Solar Wind at 327 MHz - A Comparison with Ulysses Observations" at XVII Annual meeting of the Astronomical Society of India, Guwahati, January 17-20, 1996 by Janardhan, P., Balasubramanian, V., Ananthakrishnan, S. and Srivatsan, R.

10. "On the Nature of Compact Components of Radio Sources at 327 MHz" at XVII Annual meeting of the Astronomical Society of India, Guwahati, January 17-20, 1996 by Janardhan, P, Balasubramanian, V., Ananthakrishnan, S. and Srivatsan, R.

11. "Near Infrared Observations of Nova Aquilae 1995" at XVII Annual meeting of the Astronomical Society of India, Guwahati, January 17-20, 1996 by Kamath, U.S., N.M.Ashok and T.Chandrasekhar.

12. "A High Speed near Infrared Photometer for Lunar Occultation Studies" at East Asian Meeting on Astronomy - Ground-Based Astronomy in Asia, at Tokyo, July 17-21, 1995 by Ragland, Sam, T. Chandrasekhar, N.M. Ashok and P.V. Watson.

13. "Early Dust Formation and Coronal Line Emission in a Fast Nova-Nova Herculis 1991" at East Asian Meeting on Astronomy - Ground-Based Astronomy in Asia, at Tokyo, July 17-21, 1995 by Ragland, Sam, N.M. Ashok and T. Chandrasekhar.

14. "Near Infrared Lunar Occultation Observations of Late Type Giants for Milliarc Second Scales of Angular Resolution" at East Asian Meeting on Astronomy - Ground-Based Astronomy in Asia, at Tokyo, July 17-21, 1995 by Ragland, Sam, T. Chandrasekhar and N.M. Ashok.

15. "Cosmological Size Evolution of Extragalactic Radio Sources" at IAU Symposium 175 on Extragalactic Radio Sources, Bologna, Italy, October 10-12, 1995 by Singal, A.K.

16. "GMRT-An Update and A Proposal for a VLBI Antenna in India" at IV Asia-Pacific Telescope Workshop, Sydney, December 4-7, 1995 by Singal, A.K.

17. "Peculiar Oscillations in the Microwave Emission of Jupiter during the Impact of K Fragment of Comet Shoemaker-

Levy 9" IAU Colloquium # 156 on The impact of D/ Shoemaker-Levy 9 into Jupiter, Baltimore, USA, May 9-12, 1995 by Vats, Hari Om and M.R. Deshpande.

18. "Radio Observations and Polarization Experiment during Total Solar Eclipse" at the DST-ISRO Workshop on the Total Solar Eclipse of 24 October 1995, Udaipur Solar Observatory, Udaipur, September 28-29, 1995 by Vats, Hari Om, U.C. Joshi and M.R. Deshpande.

19. "Electric Currents and Magnetic Shear Variations during Some Flares of M and X-Class" at IAU Coll. No. 153 "Magnetohydrodynamic Phenomena in the Solar Atmosphere", May 22-26, 1995, Makuhari, Tokyo (Japan) by A. Ambastha, J.M. Fontenla, and Mona J. Hagyard,

20. "Observing the Sun with Small Aperture Telescopes" at IUCAA Workshop on Instrumentation for Small Telescopes and Astronomy Programs at University Level, Feb 26-Mar 01, 1996, Mahuva, Bhavnagar University by A. Ambastha,

21. "Soft X-ray Blow- outs and Coronal Holes" at the 26th Solar Physics Division meeting of the American Astronomical Society, Memphis, Tenn., USA, June 4 - 8, 1995 by A. Bhatnagar.

22. "Total Solar Eclipse observations from Stratosphere." at the XVII Astronomical Society of India, Guwahati, Assam, January 17-20, 1996 by A. Bhatnagar,

23. "GONG Telescope operational at Udaipur Solar Observatory" at the XVII Astronomical Society of India, Guwahati, Assam, January 17-20, 1996 by Sushant C. Tripathy, A. Bhatnagar, SK Gupta, N Jain, Frank Hill and GONG Team.

24. "Total Solar Eclipse Observations from MiG-25, at 80,000 ft height." at the National Meeting on Total Solar Eclipse of October 24, 1995, February 26 - 27, 1996, held at Indian Institute of Astrophysics, Bangalore by Bhatnagar, A., Mukherjee, S., Babu, Y.S., Sehgal, N. K., Kamble, V.B., Pandya, R.M., Pandya, N.P., Bhavsar, K.M., and Prajapati, R.P.

25. "Observations of 24th October 1995 Total Solar Eclipse from Ground and from Canberra aircraft at 40,000 ft Altitude" at the National Meeting on Total Solar Eclipse of October 24, 1995, February 26 - 27, 1996, held at Indian Institute of Astrophysics, Bangalore by Bhatnagar, A., Nijhavan, A.K., Sehgal, N.K., Kamble, V.B., Pandya, R.M., Pandya, N.P., Bhavsar, K.M., and Prajapati, R.P.

26. "No Signature of circum-solar dust ring up to 5 solar radii from optical polarisation and near IR observations of 24 October 1995 Total Solar Eclipse" at the National Meeting on Total Solar Eclipse of October 24, 1995, February 26 - 27, 1996, held at Indian Institute of Astrophysics, Bangalore by Debi Prasad C., Ambastha, A.,

27. "A search for circum solar dust ring during solar minimum" at the National Space Science Symposium - 96, Osmania University, Hyderabad, February 6-10, 1996 by Debi Prasad, C, Ambastha, A., Gupta, S. K., Murali, K. R., Vasantha Kumar, N. G., Khekale, P. V., Bimal Sharma, Dasgupta, K. S., Kiran Kumar, A. S.,

28. "Effect of Opacity changes on the solar structure" at the International Conference on Windows on the sun's interior, TIFR, Bombay, October 19-21, 1995 by Sushant C Tripathy and J. Christensen-Dalsgaard.

PLANETARY ATMOSPHERES AND AERONOMY

29. (a) "Progress report on the All Sky Imaging Fabry-Perot Spectrometer"; (b) "Rocket results conducted during IEEY periods" and (c) "Resources for optical aeronomy at the All India Coordinated Programme on Ionospheric-Thermospheric Studies" Progress Monitoring Meeting, S.V. University, Tirupati, April 4-6, 1995 by Sekar, R.

30. "Optical Imaging of Plasma Depletions" at the XXI General Assembly of the International Union of Geodesy and Geophysics, Boulder, U.S.A., July 2-14, 1995 by Sinha, H. S. S.

31. "Irregularities in the Bottom Side of the F-region over SHAR" at the XXI General Assembly of the International Union of Geodesy and Geophysics, Boulder, U.S.A., July 2-14, 1995 by Sinha, H. S. S.

32. "Ionization Hole Experiment:- Results from a Coordinated Rocket and Ground-based Study at the Onset of ESF" at the XXI General Assembly of the International Union of Geodesy and Geophysics, Boulder, U.S.A., July 2-14, 1995 by Sridharan R.

33. "Daytime Spectrometry - Present Status and Future Propsects" at the XXI General Assembly of the International Union of Geodesy and Geophysics, Boulder, U.S.A., July 2-14, 1995 by Sridharan R.

34. "Ionospheric Experiments during the Total Solar Eclipse of 24 October 1995" at the DST-ISRO Workshop on Total Solar Eclipse of 24 October 1995, USO Udaipur, September 28-29, 1995 by Chandra, H.

35. "Optical Remote Sensing of the Upper Atmosphere during Daytime using Ground-based Spectrophotometry" at the UN Conference on Optical Physics in Space Sciences and Technology, Trieste, Italy, November 20-24, 1995 by Narayanan, R.

36. "Electrical Conductivity Variation due to Volcanic Aerosols" at the Sixth Conference of the Indian Aerosol Science and Technology Association (IASTA-95), Physical Research Laboratory, Ahmedabad, November 28-30, 1995 by Gupta, S. P..

37. "Ionospheric Tomography (in Hindi)" at the ISRO Inter Center Seminar (in Hindi), Physical Research Laboratory, Ahmedabad, January 23-25, 1996 by Chandra, H.

38. "Electrical Activity in Earth's Atmosphere (in Hindi)" at the ISRO Inter Centre Seminar (in Hindi), Physical Research Laboratory, Ahmedabad, January 23-25, 1996 by S. P. Gupta.

39. "OI 630.0 nm Thermospheric Dayglow as a Means of Investigating E and F-region Electrodynamical Processes over the Dip Equator" at the Workshop on Atmospheric Interations : Downward and Upward Coupling from and to Middle Atmosphere and Upper Atmosphere, Trieste, Italy, February 5-16, 1996 by Pallam Raju, D.

40. "Photostationary State Conditions in Different Environment Based on Measurements of O_3, NO_2 and NO at the National Space Science Symposium, Osmaniya University, Hyderabad, February 6-10, 1996 by Manish Naja.

41. "Bromine Loading in the Tropical Stratosphere" at the National Space Science Symposium, Osmaniya University, Hyderabad, February 6-10, 1996 by Patra, P. K.

42. "Measurements of N_2O and CH_4 in the Arabian Sea" at the National Space Science Symposium, Osmaniya University, Hyderabad, February 6-10, 1996 by Patra, P.K.

43. "Equatorial Plasma Bubble Evolution and its Possible Role in the Generation of Irregularities in the Lower F-region" at the National Space Science Symposium, Osmaniya University, Hyderabad, February 6-10, 1996 by Sekar, R.

44. "Fluctuation in Ozone Column over Ahmedabad during the Solar Eclipse of 24 October 1995 " at the National Space Science Symposium, Osmaniya University, Hyderabad, February 6-10, 1996 by Shah, N. C, Chakrabarty, D. K., and Pandya, K. V..

45. "High Resolution Two Dimensional Maps of OI 630.0 nm Dayglow Emission from Equatorial Latitudes - First Results" at the National Space Science Symposium, Osmaniya University, Hyderabad, February 6-10, 1996 by Sridharan, R.

46. "The Energy Inputs during Geomagnetic Storms and the Response of the Low-latitude Thermosphere- ionosphere System" at the National Space Science Symposium, Osmaniya University, Hyderabad, February 6-10, 1996 by Sridharan, R.

47. "Ionospheric Effects of the Total Solar Eclipse of 24 October 1995 over Ahmedabad" at the National Space Science Symposium, Osmaniya University, Hyderabad, February 6-10, 1996 by Vyas, G. D.

EARTH SCIENCES AND SOLAR SYSTEM STUDIES

Oceanography and Climate Studies

48. "Himalayas: Potential Reservoir for Reconstruction of Short Term Past Climatic changes and Environmental Records" at the International Workshop on Himalayan/ Tibetan Plateau Palaeoclimate, Kathmandu, Nepal, April 2-7, 1995 by Nijampurkar, V.N.

49. "Palaeoclimatic Records from the Thar Desert" at the Seminar on Palaeomonsoons: INQUA Palaeomonsoon Project, Berlin, July 1995 by Singhvi, A.K.

50. "Luminescence Chronology of Dunes and Lakes in Thar and their Correlation and Palaeo-environmental Implica-

tions: A Review" at the International Conference on Limnogeological Congress, Copenhagen, Denmark, August 21-25, 1995 by Singhvi, A.K.

51. "Late Quaternary Climatic Changes Inferred from Carbon Isotope Analyses of Peats in Southern India" at the Conference on Global Analysis, Interpretation and Modelling, Garmisch Partenkirchen, Germany, September 25-29, 1995 by Ramesh, R., R.Sukumar, G.Rajagopalan and R.K. Pant.

52. "Past Temperature Variations Inferred from ^{18}O Record of Tropical Peats in Southern India" at the Conference on Global Analysis, Interpretation and Modelling Garmisch Partenkirchen, Germany, September 25-29, 1995 by Ramesh, R.

53. "Application of Cosmogenic Beryllium-10 in Palaeoceanographic Studies" at the International Conference on Palaeoceanogrphy, Halifax, Canada, October 10-14, 1995 by Somayajulu, B.L.K.

54. "Transfer of Technology with Relation to Water Recycling, Recovery and Reuse" at the Workshop on Environment Protection: Citizen's Legal Rights and Remedies, CERC, Ahmedabad, November 17-19, 1995 by Gupta, S.K.

55. " ^{210}Pb Aerosols: Arabian Sea Regional Study" at the Sixth Conference on Indian Aerosol Science and Tech. (IAST), PRL, Ahmedabad, November 28-30, 1995 by R. Rengarajan and M.M. Sarin.

56. "Palaeoclimate History for the Last 7 ka from Nal Sarovar" at the Workshop on IGCP-349, M.S. University of Baroda, Baroda, November 17-20,,1995 by Prasad Sushma and S.K. Gupta.

57. "Stable Carbon and Oxygen Isotopic Changes and Rare Earth elements across Pre-Cambrian/Cambrian Boundary, Lesser Himalaya" at the Symposium on Recent Advances in Geological Studies of NW Himalaya and the Foredeep held in Lucknow, GSI, February 21-23, 1996 by Bhattacharya, S.K.

58. "Non-mass Dependent Isotopic Fractionations and its Relevance in Isotopic Standardisation" at the Advisory Group Meeting on Stable Isotope References and Intercomparison Materials at IAEA, Vienna by Bhattacharya, S.K.

59. "Status of Stable Isotope Standardization in Major Indian Laboratories" at the Advisory Group Meeting on Stable Isotope References and Intercomparison Materials at IAEA, Vienna by Bhattachaya, S.K.

Solar System and Geochronology

60. "Cosmic Ray Gradients in the Heliosphere Based on Isotope Production Rates in Meteorites " at the 24th International Cosmic Ray Conference held at Rome, Italy, August 28 - September 8, 1995 by Bhandari, N. and Ballabh, G.M.

61. "Solar flare tracks in Rio Negro (L4) chondrite" at the 24th International Cosmic Ray Conference held at Rome, Italy. August 28 to September 8, 1995 by Bhandari, N., Cini Castagnoli, G., Bonino, G. and Suthar, K.M.

62. "Observation of Correlated Calcium-41 and Alluminium-26 in CV3 Hibonites" at the 58th Meteoritical Society Meeting, Washington D.C., USA, 11-15 September (1995) by Goswami, J.N., S.Sahijpal, G.Srinivasan and G.J.Wasserburg.

63. "I-Xe systematics in Sulfide and Silicate Phases in Individual Chondrules from the Semarkona Meteorite" at the 27th Lunar and Planetary Science Conference held at Houston, USA, 18-22 March (1996) by Kehm, C., Swindle, T., Goswami, J.N. and Hohenberg, C.M.

64. "Alkali Basalts in the Deccan Traps: Mineralogy" , at Winds of Change, Workshop Dedicated to Professor William Dixon West, held at Bombay, 25-30 January (1996) by Krishnamurthy, P.and Pande,K.

65. "Noble Gases in Mantle Xenoliths from San Carlos Arizona" at the 3rd International Conference on Rare Gas Geochemistry held at Amritsar, 10-14 December (1995) by Mohapatra , R. K., Murty, S.V.S. and Pande, K.

66. "Nitrogen and Light Noble Gases in Mantle Xenoliths from Kutch and a Dunite from Reunion" at Winds of Change, Workshop dedicated to Professor William Dixon West, held at Bombay, 25-30 January (1996) by Mohapatra, R.K., Murty, S.V.S. and Pande, K.

67. "Excess Argon-36 in the Efremovka meteorite: Evidence for Live Chlorine-36 in the Early Solar System?" at the 58th Meteoritical Society Meeting, Washington D.C., USA, 11-15 September. (1995) by Murty, S.V.S., Shukolyukov, Yu.A. and Goswami, J.N.

68. "Identification of Cretaceous-Tertiary Boundary in Anjar Intertrappeans and its Relation to Deccan Volcanism" , at Winds of Change, Workshop dedicated to Professor William Dixon West, held at Bombay, 25-30 January. (1996) by Venkatesan, T.R., Bhandari, N., Kusumgar, S., Pande, K. and Shukla P.N.

THEORETICAL PHYSICS

Astrophysics

69. (i) "Accretion Disk around a Compact Object....Magnetic Field", and (ii) "Charged Particle Trajectories in the Magnetosphere of a Slowly Rotating Compact Object", at the International GRG Conference, Florence, Italy, August 6-12, 1995 by Prasanna, A.R.

70. (i) "Charged Particle Trajectories in the Magnetosphere of a Slowly Rotating Compact Object" and (ii) "Centrifugal Force and Ellipticity Behaviour of a Slowly Rotating Compact Object", at the International Conference on General Relativity and Cosmology, IUCAA, Pune, December 12-19, 1995 by Prasanna, A.R.

Plasma Physics

71. "Integrability of Coupled Upper-hybrid and Magnetoacoustic Waves in a Magnetized Plasma", in International Topical Workshop on Plasma Physics : Coherent Processes in Nonlinear Media, at the International Centre for Theoretical Physics, Trieste, Italy, October 16-20, 1995 by Rao, N.N.

Meteorology and Climate Studies

72. "Sensitivity of South Asian Summer Monsoon to Surface Albedo", at the TROPMET-96 National Symposium on Meteorology and Natural Disasters, Andhra University, Visakhapatnam, February 14-17, 1996 by Kasture, S.V.

Nonlinear Dynamics

73. "Periodic Orbit Bifurcations and Quantum Spectra" , at the International Conference on Spectroscopy : Perspectives and Frontiers, BARC, Bombay, January 3-5, 1996 by Sheorey, V.B.

LASER PHYSICS AND QUANTUM OPTICS

74. "Quantum Noise in Optical phase conjugation Performed in an Atomic vapor" at Rochester Conference on Coherence and Quantum Optics on June 7 - 11, 1995, by M.Y.Lanzerotti, R.W.Schirmer, A.L.Gaeta and G. S. Agarwal.

75. "Quantum Fluctuations as the Origin of Laser Beam Filamentation" at Rochester Conference on Coherence and Quantum Optics on June 7 - 11, 1995, by E. Nagasako, R. Boyd and G. S. Agarwal.

76. "Quantum Theory of Filamentation" at Quantum Electronics and Laser Science Conference, Baltimore May, 1995, by E.M.Nagasako, R.Boyd and G. S.Agarwal.

77. "Spatial Coherence of Radiating Atoms in Resonance Regions" at Rochester Symposium on Spectral effects in Collective Phenomena on June 7 - 11, 1995, by M.W.Kowarz, E.Wolf and G. S. Agarwal.

78. "Coherent States for Kronecker products of Non-Compact Groups: Formulation and Applications " at Fourth International Conference on Squeezed States and Uncertainty Relations, China on June 5 - 8,1995, by B.Bambah and G. S. Agarwal.

79. "Quantum Mechanics of Ionic Motion in a Paul Trap", at XXII National Symposium of the Optical Society of India on Optics and Opto-Electronis,Instruments Research and Development Establishment, Dehra Dun on March 14, 1996 by Arun Kumar.

LIBRARY

80. "Linking Library Metronets at the Workshop: On Problems & Prospects of National Library Network", at ATIRA, Ahmedabad, February 14, 1996 by Bharucha Rhoda.

81. "Networks Time Saving Devices in Libraries" at the Conference on Automation of Libraries of Educational and Research Institute, CALIBER - 96, at M.S. University & INFLIBNET, Baroda, February 15-17, 1996 by Bharucha Rhoda.

82. "ADINET Network of Ahmedabad Libraries at the Conference on Automation of Libraries of Educational and Research Institute CALIBER - 96", at M.S. University & INFLIBNET, Baroda, February 15-17, 1996 by Parikh Surangi.

ELECTRONICS LABORATORY

83. "Simulation of Implant of Higher Function in Randomly Connected Artificial Neural Network" at the XIVA International Conference on Cognitive Science (ICCS-95) at NIIT, Delhi, December 1995 by Mazumdar H.S and Rawal P. Leena.

84. "A Skull-Face Superimposition using Computer Graphics" at the Interantional Conference of Forensic Science Laboratories at Auckland, New Zealand, 1995. by Mazumdar H.S., Rawal P. Leena and Nandi A.D.

Science at PRL

The scientific programmes of the Astronomy and Astrophysics division consist of high angular resolution studies of evolved stars by the method of Lunar Occultations, solar physics, velocity field studies in planetary nebulae and in regions of star formation, imaging studies of active galaxies and short time variability studies of active galactic nuclei. In addition topical programmes like Imaging Spectroscopic studies of the solar corona during total solar eclipses and infrared photometric, polarimetric and imaging studies of comets are also pursued. The current year witnessed two major events - a total Solar eclipse on 24 October 1995 and the appearance of a bright comet, comet Hyakutake (1996 B2). The scientists of the division carried out a number of observations of both these spectacular events which are described below along with the regular scientific programmes of the division.

Infrared and Optical Astronomy

High Angular Resolution Studies of Stellar Sources in the Near Infrared using Lunar Occultation Techniques

Lunar occultation observations in the near Infrared can provide occultation light curves with Signal to Noise ratio high enough for deriving accurate angular sizes of late type giants and supergiants at the level of a few milliarcseconds. A careful analysis technique can also reveal the presence of fainter circumstellar structures at the level of tens of milliarcseconds. Lunar occultation of nearly a dozen IR sources have been successfully observed at the Mt. Abu observatory's 1.2 m telescope during 1995-96 using the high speed Infrared photometer. Detailed analysis is in progress on these occultation light curves which include three interesting pulsating variable stars (IRC +20111, IRC -20563, IRC 20112).

The detailed analysis of the occultation light curve of the M1 supergiant star TV Gem was completed during the year. A precise angular diameter of 4.9$\pm$0.3 milliarcseconds and an effective temperature of 3670$\pm$125 K has been derived for the source. An inner circumstellar shell at 20 stellar radii has also been detected for the first time around TV Gem. A radiative transfer model constrained by our occultation observations, 9.7 micron silicate feature strength and far infrared excess seen in IRAS observations shows that dust around TV Gem is confined to two zones - an inner zone at about 20 stellar radii and another outer zone at about 500 stellar radii. Sporadic dust condensation processes controlled by irregular mass loss appear to be operating in this supergiant similar to the picture in the well known supergiant alpha Orionis.

(T.Chandrasekhar, N.M.Ashok, Sam Ragland, Anandmayee Tej and K.S.B.Manian).

Near Infrared Photometric Studies of Short Period Algol Binaries

The Algol eclipsing variables are the proto-type of semi-detached binary systems. They consist generally of an early type star of spectral type B or A accompanied by a late type companion of spectral type F, G or K but occasionally A. The more massive early type star is the detached component that lies within the main-sequence band while the less massive late-type star is a subgiant or giant that fills its Roche lobe. The reason for the apparent paradox of less massive star being more advanced in evolution than its more massive companion - the Algol paradox - is the mass transfer that has reversed the original mass ratio.

At optical wavelengths the primary component dominates the observed light. The depth of the secondary minimum is most of the time less than 0.1 mag at optical wavelengths. The low temperature of the secondary components enhances their contrast at infrared wavelengths and results in pronounced secondary eclipses. Hence near-infrared light curves of Algols provide improved information about the properties of the secondary component. At PRL we have taken up a programme of near infrared studies of short period Algols. As part of this programme light curves covering entire orbital phase of the binary will be obtained. During 1995-96 observing season J (1.25 microns) and K (2.2 microns) band light curves of two such systems, namely, R Canis Majoris (Period = 1.1359 days) and RZ Cassiopeiae (Period = 1.1952 days) have been obtained - these are the first near infrared light curves of these systems.

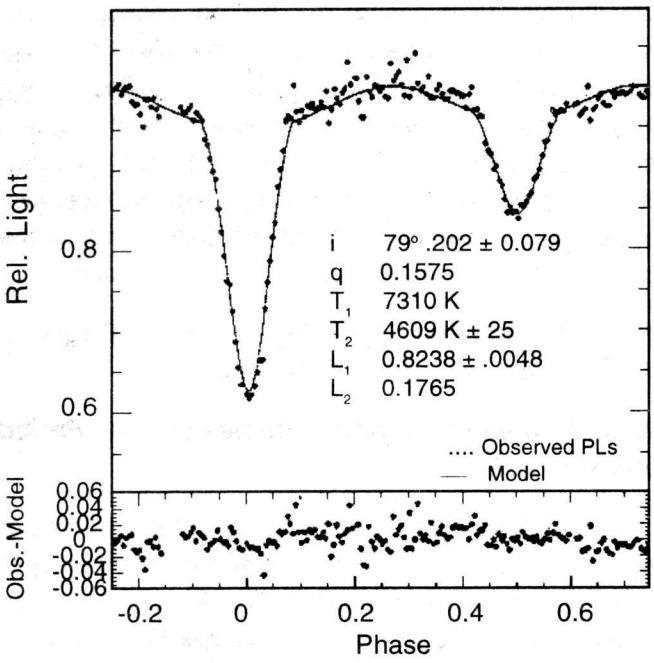

Fig. 1.1 : Light Curve in the near Infrared J band (1.25 microns) from the eclipsing binary star R Canis Majoris. The light curve has been constructed from ~ 600 photometric observations made at the 1.2m Mt. Abu telescope in 1995-96.

i : Angle of inclination in sky plane

q : Mass ratio of the binary

T_1 : Effective temperature of primary star

T_2 : Effective temperature of secondary star

L_1&L_2 : Fractional luminosities of primary and secondary respectively and T_1 are fixed in the analysis. The model fit is based on Wilson's light curve interpretation program.

The peculiarity of R Canis Majoris (R CMa) is its unusually small mass ratio q=0.158, q being m_2/m_1 where m_2 and m_1 are the masses of secondary and primary components respectively. Such a low mass ratio coupled with the low mass of secondary, $m_2 = 0.168\ M_o$, indicates significant mass loss from the system. RMa CMa was observed from the Mt. Abu observatory with the 1.2 m telescope from December 1995 to March 1996. About 600 observations were made in J and K bands adequately covering both primary and secondary minima as well as other phases (**Fig.1.1**) As expected the secondary minima in these bands are deeper than the ones in the optical bands.

(N.M.Ashok, T.Chandrasekhar and P.V.Watson)

Infrared Studies of Classical Novae

Nova Cassiopeiae 1995 was studied in 1995-96 as part of the ongoing programme of monitoring classical novae in the near-infrared. Discovered by M. Yamamoto on 24 August 1995, this nova was observed at Mt. Abu Infrared Observatory right from the beginning of the observing season; our coverage extends up to February 1996. After remaining at visual magnitude 9 for a long time the nova suddenly brightened up by 2 magnitudes in December. A correlated brightness increase is seen in the near-IR also. Our data is summarized in the accompanying figure (**Fig.1.2).**

This nova is similar to nova HR Del which erupted in 1967. The evolution of the nova is slow and we hope to gather more useful data on this nova in the next observing season.

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

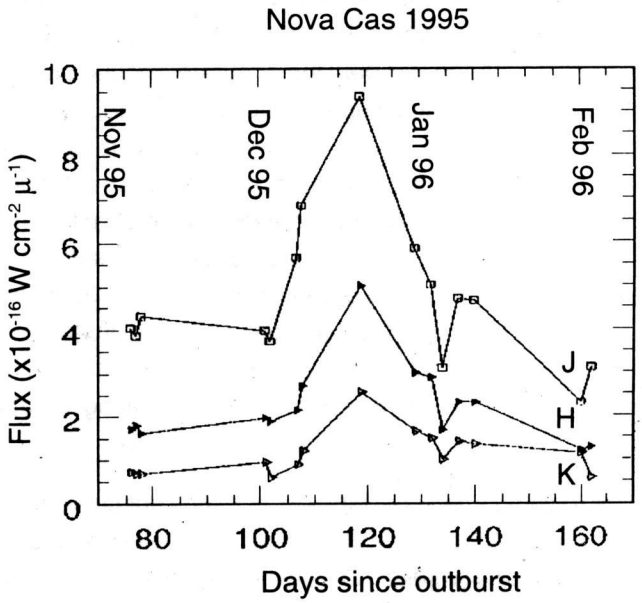

Fig. 1.2 : Light curve of Nova Cassiopeiae 1995 in JHK near infrared bands. August 24, 1995 is taken as outburst date. The brightening of the nova in Dec. 1995 is clearly seen.

Infrared Observations of Comet Hyakutake

Infrared observations are important for understanding the dust distribution in the coma and tail of a comet and also to follow up the variations in the dust tail structure as the comet reaches perihelion and recedes away from the sun. Comet Hyakutake (1996 B2) was observed on several days in late March - early April 1996 using the Infrared photometer at the 1.2 m telescope of Mt. Abu Observatory. Using the larger throw angular chopper, observations were mainly carried out at the wavelength of 2.2 microns (K band). A few observations at 1.2 microns (J band) and 1.65 microns (H band) were also made. The observations were made under difficult observing conditions - twilight, close to the telescope limit (low altitude) and even at small solar elongations. The comet was observed a week before perihelion passage at a heliocentric distance of 0.355 AU. The thermal component of cometary emission was detected in the K band. A comparative study of the IR behaviour of Comet Hyakutake with those of earlier bright comets like Comet Ikeya-Seki, Comet Kohoutek and Comet Halley is in progress.

(T.Chandrasekhar, N.M.Ashok, Anandmayee Tej, P.V.Watson, U.S.Kamat, K.S.B.Manian and C.K.Vishwanath)

Schmidt Images of Comet Hyakutake

A Schmidt camera (8 inches in aperture f/1.5) which has a wide field of view of 6 degrees x 4 degrees in the sky was mounted on the drive of the 1.2 m telescope at Gurushikhar specially for imaging the tail structure in Comet Hyakutake in March-April 1996. Many excellent cometary images using this camera were recorded on kodak 2415 fine gain film during the passage of the comet close to the earth in late March and April 96 under good sky conditions (**Fig.1.3**) . The extent of the tail and the structures in it show distinct changes from one day to the next. The data is in the process of being digitized and analysed to study both the evolution of the dust tail and the interaction of the solar wind and the interplanetary magnetic field on the plasma tail of the comet.

(N.M.Ashok, T.Chandrasekhar, J.N.Desai, U.S.Kamat, and Anandmayee Tej)

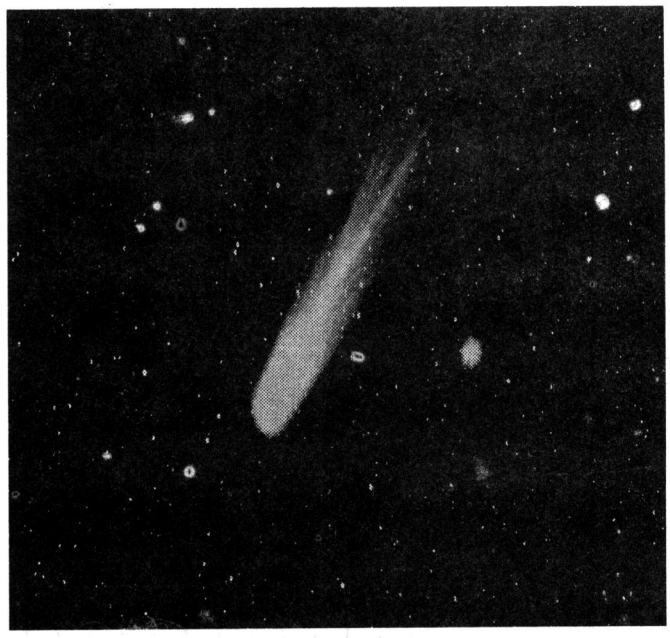

Fig. 1.3 : Schmidt photograph of Comet Hyakutake (C/1996 B2) taken on 1996 April 9 at about 2030 hours IST from Gurushikhar observatory. Exposure time was 10 minutes, on Kodak 2415 film. The intricate structures in the coma and tail can be readily seen. The bright star in the frame is the famous eclipsing binary star Algol. The separation between the star and the cometary nucleus is about 1 degree in the plane of the sky. The comet was at a distance of 0.49 AU from earth and 0.71 AU from the sun (IAU = 150 million km).

Polarization and Photometric Study of Comet Hyakutake

Photopolarimetric study on Comet Hyakutake was conducted by PRL scientists using the IHW filter set, which consists of 3 continuum band : 3650/80; 4845/65 and 6840/90 and five molecular emission bands : CN(3871/50); C_3(4060/70); CO^+(4260/65); C_2(5140/90) and H_2O^+(7000/175) (all figures are in Angstroms, central wavelength/band pass). The dust properties were studied using the continuum band polarization. The observed data were compared with the theoretically calculated values based on Mie Scattering Theory. The results show (**Fig. 1.4 & 1.5**) that the dust characteristic of Comet Hyakutake is similar to that of Comet Halley, though Hyakutake is a dynamically younger comet as compared to Comet P/Halley. The data were also compared with

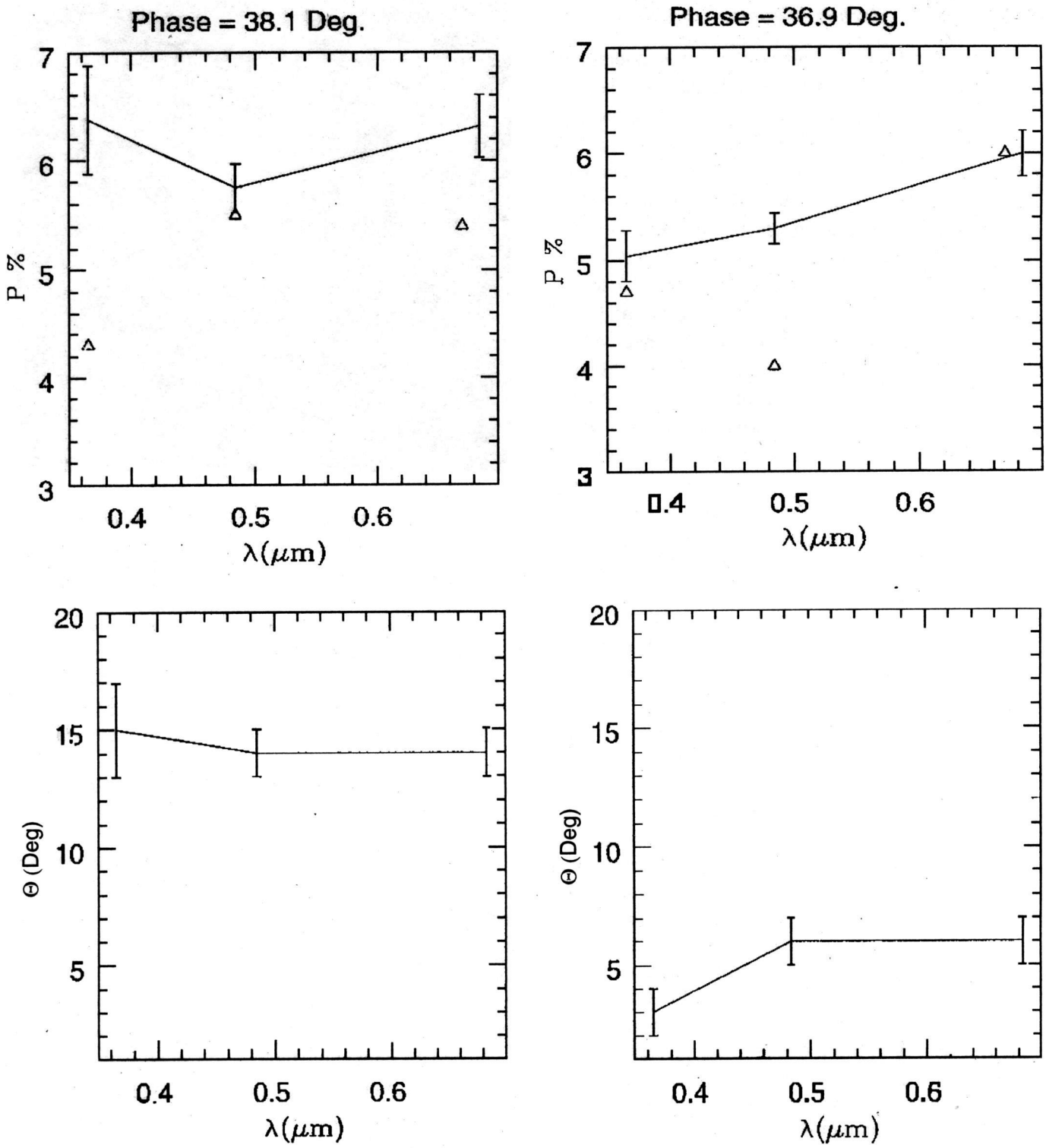

Fig. 1.4 : Wavelength dependence of observed degree of percent polarization (% P) and position angle (θ) for comet Hyakutake. Present observations are connected with solid line. The symbols represent data for comet P/Halley.

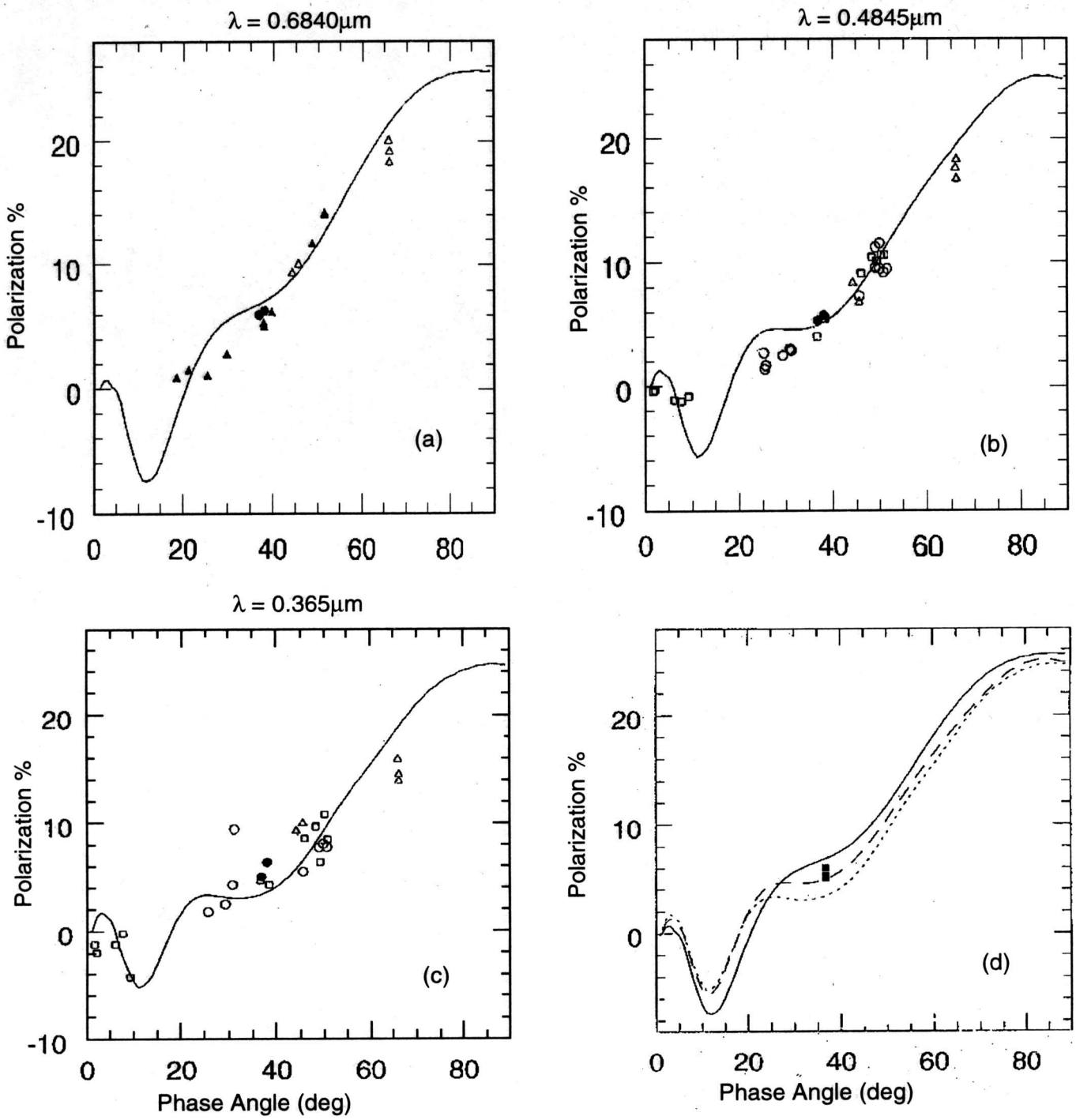

Fig. 1.5 : Polarization percentage of comet Hyakutake plotted as a function of phase angle. The observed data are: Filled circles - present observations. The other symbols represent the observations for Comet Halley, For Figs. (a-c), the solid line represents theoretical results for respective wavelengths and for (d) the theoretical curves at wavelengths 0.6840 microns. 0.4845 microns, and 0.3650 microns are shown by solid line, dotted line and dashed line, respectively. Also plotted in this figure are Hyakutake observations at phase angle 38.1° (filled squares).

Comet Austin, which shows a different behaviour. These results will help further our understanding on the formation of comets.

(U.C.Joshi, M.R.Deshpande, K.S.Baliyan, Hari Om Vats, S. Ganesh, Aparna Chitre)

Total Solar Eclipse of October 24, 1995 - Observations of the Solar Corona from Neem Ka Thana

The investigation of the thermal and velocity structure in the solar emission corona during total eclipses of the sun provides valuable pointers for addressing the still unsolved problem of the heating of the corona. Using Imaging Fabry-Perot interferometric techniques, PRL has been conducting studies of the solar emission corona since the total eclipse of 1980 which occurred at the peak of solar activity. The total eclipse of 24 Oct.1995, though a brief one lasting less than a minute, still provided a good opportunity for studying the solar corona close to the minimum of the solar cycle. The eclipse experiments were conducted from the centre of the totality belt at Neem Ka Thana (Rajasthan). All three major coronal emission lines were studied interferometrically:

a) λ 5303 A (Green line due to [Fe XIV] originating at ~ 2 million degrees Kelvin)

b) λ 6374 A (Red line due to [Fe X] originating at ~ 1 million degrees Kelvin (**Fig.1.6**)..

c) λ 5694 A (Yellow line due to [Ca XV] originating at temperature near 5 million degrees Kelvin.

In addition to Fabry-Perot experiments direct imaging of the corona in these lines as well as in white light was also simultaneously accomplished with a 8 inch f/10 telescope system. The interferogram and filtergrams obtained on film during the totality have been digitised and detailed analysis is in progress to elucidate the temperature and velocity field structure in a solar minimum corona.

(J.N.Desai, B.G.Anandarao, T.Chandrasekhar, N.M.Ashok, and M.S.Nandakumar)

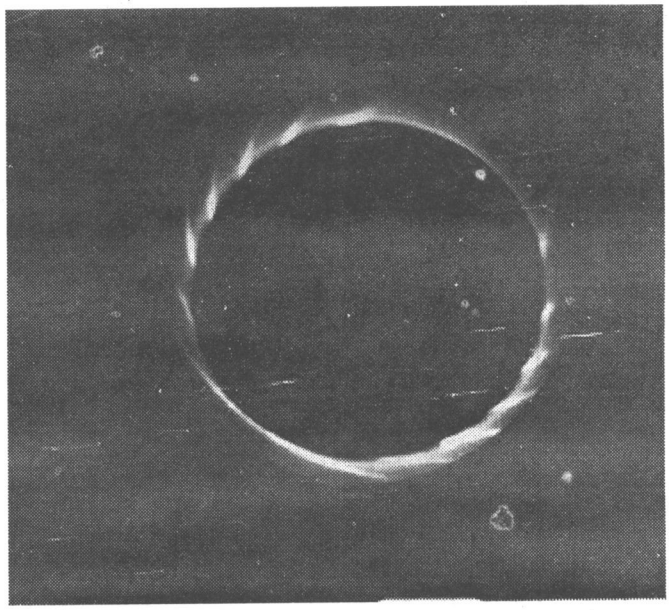

Fig. 1.6 : Fabry-Perot Interferogram in the red coronal line (6374A) due to [Fe X] ions in the solar corona of October 24 1995. Exposure time was 30 seconds in preflashed Kodak 2415 film. The interference fringes are off centerd with respect to the solar centre to obtain near radial coverage in some at some azimuths.

Solar Eclipse Experiments at Lunkaransar (Rajasthan) and Ahmedabad

During the solar eclipse of Oct.24, 1995 we conducted optical experiments inside the path of totality (at Lunkaransar (near Bikaner)) and radio observation also out of it at Ahmedabad. At Lunkaransar two cameras with focal length 200 mm and 400 mm (zoom lenses) were used on Kodak Film 2415. Four images in different orientation of polaroid sheet were recorded in each camera during the totality period. The data, is being analysed to determine coronal electron density distribution during the minimum phase of the solar cycle.

At Ahmedabad, three radiometers operating at 1.707 GHz, 2.54 GHz and 4.15 GHz were pointed towards Sun. The measurements were carried out on 23, 24 and 25 October 1995. The 2.54 GHz radiometer had no track facility, it was manually used to measure solar flux every 10 minutes. The other two systems with full tracking

capabilities were operated in collaboration with Space Applications Center, Ahmedabad. Preliminary data analysis indicate peculiar enhancements and bite outs in solar radio fluxes at 1.707 GHz and 4.15 GHz. Detailed analysis and comparison of radiometric data with coronal structures and other optical features on solar surface is being carried out.

(Hari Om Vats, M.R.Deshpande, U.C.Joshi, N.M. Vadher, Harish Chandra, G.D.Vyas, K.S.Lali, M.B.Dhadhania, K.J.Shah, C.R.Shah, N.V.Dalal, V.D.Patel and D.R.Vinchhi).

Studies on Post-AGB Evolution of Intermediate Stars - Planetary Nebulae

We have made observations using the high-resolution Imaging Fabry-Perot Spectrometer (IFPS) with the 1.2m Mt. Abu Infrared Telescope on some selected planetary nebulae (PNe), namely, NGC 246, NGC 1514, NGC 2610, NGC 3587 and NGC 4361. All these objects were selected on the basis of having multiple shells. Observations were made with the aim of obtaining the spatio-kinematic information on these objects from which the relative expansion of different shells and the radial variation of expansion velocity within a single shell may be inferred. The emission line selected for this purpose was the forbidden line from the doubly ionized oxygen, [OIII] 5007A.

The analysis of the data on NGC 1514 has been taken up. These are the first detailed kinematic observations on this nebula. The PN is round and amorphous in its morphology and is a moderate to high ionization nebula. Its central star is an eclipsing binary and hence a prominent bipolar morphology is expected; however, the structure as seen in He I and [OIII] images shows a moderate bipolar morphology.

Preliminary results of the IFPS data analysis show at the centre of the nebula, the maximum split in the 2-component line profile which corresponds to an expansion velocity of 20 km/s (**Fig. 1.7**). There seems to be a general decrease in the expansion velocity away from the central star. At a few positions on the nebula, 3-component line profiles were observed, the 3rd component of

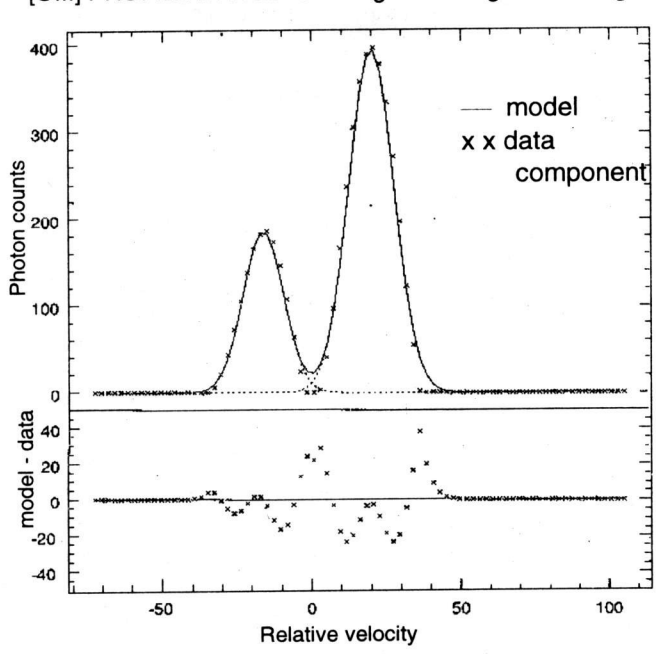

Fig. 1.7 : The [OIII] 5007 A line profile near the central regions of the planetary nebula NGC 1514 taken with the IFPS at the 1.2 m telescope, Mt.Abu.

which may be caused, among other mechanisms, by the presence of bullets of matter ejected by the progenitor star. While it is rather early to draw a firm conclusion, full spatio-kinematic field for which the analysis is in progress, would show the real structure of the nebula.

(B.G.Anandarao, C.Muthu, F.M.Pathan, H.I.Pandya, R.T.Patel, N.S.Jog and K.S.B.Manian).

International Campaign on the Be Star, Gamma Cassiopeae

Gamma Cas is a Be star of spectral type B0.5IVe and had shown, on several occasions in the past, rapid variability in emission/absorption lines. We have participated in an international multi Wavelength campaign in January 1996 which involved X-ray observations from ROSAT, UV observations from IUE satellite and optical observations of this star from a few ground-based observatories to give an adequate time coverage. The idea was to find inter-relationships between possible high-energy flare-type activity (monitored by ROSAT & IUE) and the low-energy (optical) activity on the photosphere and the

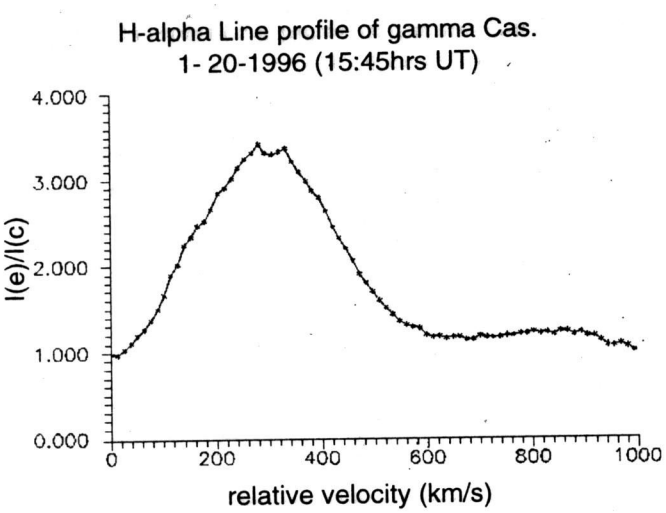

Fig. 1.8 : H alpha line profile from the Be star gamma Cassiopeae observed using the central-fringe-scanning Fabry-Perot Spectrometer at the 1.2 m telescope, Mt.Abu.

circumstellar matter of the star. We have contributed to this endeavour by making unique observations on the star in the H alpha line in emission (and hence arising from the circumstellar matter ejected by the star) using the central-fringe-scanning Fabry-Perot Spectrometer (FPS) (**Fig. 1.8**). Data analysis is in progress.

(B.G.Anandarao, A.Chakrabarty, F.M.Pathan, R.T.Patel, H.I.Pandya and N.S.Jog)

Microwave Bursts from Jupiter during the Impact of K, N, P2 and S Fragments of Conset SL-9 on Jupiters

Bursts of microwave emission were observed during the impacts of K, N, P2 and S fragments. It was noted that K and N impacts produced multiple enhancements for a period of around 40 and 20 minutes respectively. We believe that the fragments K and N further fragmented and produced multiple enhancements. We compared the normalized intensity of the burst with the size of the impactors and their class from Hubble Space Telescope observations. No co-relation between burst intensity and impactor's size and class could be derived.

(M.R.Deshpande, Hari Om Vats, N.M.Vadher and K.J.Shah)

Characeristics of Microwave Intensity Variation from Jupiter during K Fragment of SL-9 Impact on Jupiter

The study brings out the following features about the microwave emission from Jupiter during the impact of K fragment of comet SL-9:

1. There are three significant enhancements in the microwave emission. This is perhaps due to the further fragmentation of K-fragment while impacting on Jupiter.

2. There are almost periodic oscillations whose frequency seems to increase (from 03 Hz to 1 Hz) with time and then gradually return to the almost initial value. The peak to peak amplitude of these oscillation is ~34% with night variations of the Jupiter's total microwave emission. Assuming that microwave emission from Jupiter consists of thermal and non-thermal (synchrotron radiation), in equal strengths it is only the non-thermal emission which is affected by the collision of cometary fragments; the peak to peak amplitude of the oscillation would be ~68% of the normal synchrotron emission from Jupiter.

3. At the time of largest enhancement during this event there are aperiodic variations with a time scale of few minutes.

4. The periodic and aperiodic variations indicate scales of moving emitting or modulating regions of 0.5 to 1.5 kms and 120 to 300 kms respectively. It appears that the large scale (~ few minutes) aperiodic variations are due to the gravity waves (whose time scales are in this range) created by the impact of the comet's fragment. The faster periodic oscillations (~ 1-3 secs period) could have been caused by magneto spheric modulation of Jupiter's microwave emission. The oscillations are peculiar and seen only during the impact of K-fragment of SL-9. This work was a collaborative program with Space Applications Center.

(Hari Om Vats, M.R.Deshpande, N.M.Vadher and K.J.Shah)

Characteristics of 30 Sept.1993 Solar Radio Burst

We analysed the data obtained for this metre wave burst by new Hiaraiso radio spectrograph and the high time resolved single frequency (103 MHz) observations recorded at Thaltej and Rajkot. The burst peaked at 100 MHz which corresponds to coronal plasma density ~ 1.24x10 el/cc. Radio emission in this event was cut off at the plasma density of 6.3x10 el/cc. The full width at half maximum (FWHM) of the spectrum was around 165 MHz. Full widths at 0.5 and 0.0 in the cross correlogram of Thaltej and Rajkot records at 103 MHz were 3.2 secs and 10.1 secs. The multiburst spikes appeared to have been caused by the relativistic beam of particles in the solar corona. This work was carried out in collaboration with Saurashtra University, Rajkot and Communication Research Laboratory, Japan. (Indian J. Radio Space Phys. (Accepted for publication))

(Hari Om Vats and M.R.Deshpande)

Tracking Interplanetary Disturbances

Based on the advance predictions of two flare generated shock fronts, obtained from the Space Environment Laboratory (SEL, NOAA, Boulder), observations of interplanetary scintillation (IPS) were carried out with the Ooty Radio Telescope (ORT) on a grid of appropriately located sources during the period 31 October to 5 November 1992. Solar wind velocities were derived by fitting model spectra to the observed spectra and two travelling interplanetary disturbances were detected. Both disturbances were traced back to an active region on the sun which was located close to a large coronal hole. The roles of flares and coronal holes in producing such disturbances were examined and it was shown that in the present case both the coronal hole and the active region probably played key roles in generating the two IPS disturbances.

It is important to note that two temporally distinct IP transients were predicted in advance by a theoretical model of propagation of IP shocks, on the basis of the observations of temporally separated events on the solar surface and both were detected unambiguously by using the technique of IPS. While this is not the first instance where IPS velocity observations have been traced back to solar events these are the first observations where IPS has been used to obtain measurements with high enough spatial resolution to form an approximate image in the IPM of regions of high and low speed. The methodology adopted for detecting the IPD's was, in essence, the use of lines of sight to a set of spatially distributed compact radio sources as a rapidly movable "picket fence". This was possible owing to the large collecting area and the steerability of the ORT.

(Solar Physics (Accepted for publication))

(P.Janardhan)

Unified Scheme of Active Galactic Nuclei

The orientation-based unification scheme of powerful radio galaxies and quasars was examined. Comparison of the space distributions and the physical size distributions of radio galaxies and quasars showed strong evidence against the unified scheme. The work is in progress on a larger sample (~ 1050 sources) of radio galaxies and quasars, in collaboration with some Italian Astronomers. The redshift and size distribution of sources in such a large sample is being studied to further test the unified scheme of radio galaxies and quasars. (Mon. Not. R. astr. **278**, 1069 (1996)).

(A.K.Singal)

Radio Source Mapping

Total intensity and polarization maps were produced for a sample of 4 giant radio sources. These were observed at 2.8 cm with the Effelsberg Radio Telescope, Bonn in collaboration with some German astronomers. Data analysis of some more giant radio sources is in progress, these were observed with the Westerbork Radio Telescope, Netherlands and the European VLBI Network (EVN).

(A.K.Singal)

General Relativity/Classical Electro-dynamics

It was shown theoretically that a freely falling charge in a uniform gravitational field does not radiate. It was

further shown that a charge accelerated uniformly with respect to an inertial frame also does not radiate.

(A.K.Singal)

Variability Studies of BL Lac Object OJ287

OJ287 shows variations, at different timescales, in flux and polarization at various wavelengths. By assuming the emission mechanism to be synchrotron radiation by high energy electrons with single power law energy distribution, a theoretical spectrum in the frequency range 10^{11}-10^{17} Hz is calculated and compared with multifrequency simultaneous observations. Estimated upper and lower cut off frequencies are used to get theoretical values of variability timescales and magnetic field in the emission region. These timescales are compared with those obtained from short timescale variability observations. This study indicates a multicomponent emission source in OJ287.

During the year variability study of BL Lac object OJ287 was continued. Polarimeteric monitoring was done on a couple of nights during the International Campaign on OJ287. The data are being looked into in light of the observations made by other groups at different frequencies. Observations were also made on another source 3C66A.

To study the time variation of flux, observations were also made with a liquid Nitrogen cooled CCD camera, the average total sample time being about 2 min. Data is being analysed.

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

Study of Starburst Galaxies

A few more galaxies were studied this year under the ongoing program of studying starburst galaxies. A couple of compact starbursts were observed using a CCD camera on the 1.2 m telescope. The U band images of three galaxies studied previously (Mrk 35, Mrk 799 and Mrk 266) were obtained at the 1 m telescope of UPSO, Nainital. Two more starburst galaxies, Mrk 708 and Mrk 1194 were also observed in U, B, V, R, I bands. Mrk 708 is a face-on galaxy. The contour map of Mrk 708 is shown

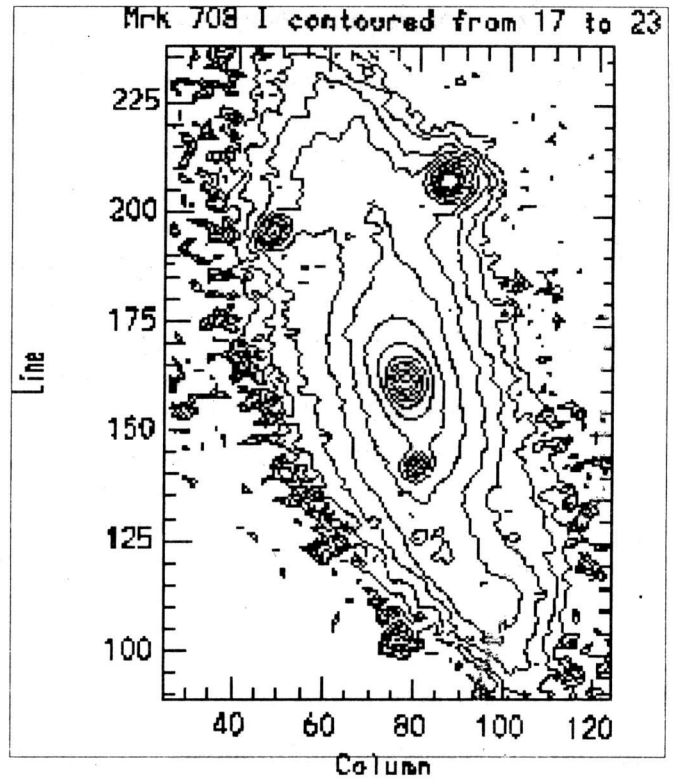

Fig. 1.9 : The contour map of Mrk 708 in I filter from 17 to 23 magnitude per square arcsecond.

in **Fig.1.9**. The color map of this galaxy is rather smooth except for small variations in the nuclear region.

(U.C.Joshi, Aparna Chitre)

Infrared Polarimetery

A state-of-the-art infrared polarimeter which was partly funded by DST is fully operational now. This is the first instrument of its kind in the country. The instrument was used on 1.2 m telescope for observations. Star alpha Boo was observed to check the performance of the instrument. The instrumental polarization has been detected at a level 0.31$\pm$0.26% in K band. 100% polarized light is recorded as 98.8$\pm$0.32% in K band. In K band VY CMa shows polarization 4.3 $\pm$0.57%. These results are quite satisfactory.

(U.C.Joshi, K.S.B.Manian, J.S.Chauhan, S.Ganesh, Aparna Chitre, Vishal Shah, M.R.Deshpande)

Photoabsorption Cross Sections of NiXIX ion

Theoretical cross sections for highly ionized ions are required for the diagnostic and modelling of laboratory and fusion plasmas since these are not readily available experimentally. We use simple C-I wavefunctions and carry out R-matrix calculations to obtain photoionization cross sections for many excited states of this ion. Lowest two target states are included in the basis function expansion since other states lie very high in energy. Cross sections for the photoionization of NiXIX from its $2s^2 2p^5 3s\,^1P^o$, $2s^2 2p^5 3p\,^3S^e$, $^3P^e$, $^3D^e$ excited states are calculated in a wide energy range. These are dominated by the Rydberg series of resonances.

(K.S.Baliyan)

Solar Astronomy at Udaipur Solar Observatory

Large Two-Ribbon Flare of March 28, 1990

Solar flares represent catastrophic release of energy, and it is of interest to find how they are triggered. A large solar flare was observed on March 28, 1990/07:30 UT in NOAA 5988, around the magnetic inversion line as delineated by a dark filament, which underwent significant changes. A new emerging flux region close to the filament, its rapid restructuring and rotation before the flare, suggest that it provided the trigger mechanism for the flare.

(A. Ambastha, S.C. Tripathy and D. Prasad C.)

Total Solar Eclipse Observation from High Flying Aircraft

Solar eclipse observations were earlier made from altitudes of 37,000-40,000 ft by Concord and other US Airforce planes. However, during the October 24,1995 total solar eclipse, first ever attempt was made by the USO team to take photographs of the extended solar corona, using IAF's MiG-25 and Canberra aircraft flying at 80,000 ft and 40,000 ft, respectively, in collaboration with the Indian Airforce (IAF), Space Applications Centre, and the National Council of Science and Technology Communication.

(A. Bhatnagar, Gr. Capt. S. Mukerji, Sq. Ldr. Y.S. Babu, Wg. Com. A.K. Nijhavan, N.K. Sehgal, V.B. Kamble, R.M. Pandya, N.P. Pandya, K.M. Bhavsar, and R.P. Prajapati.)

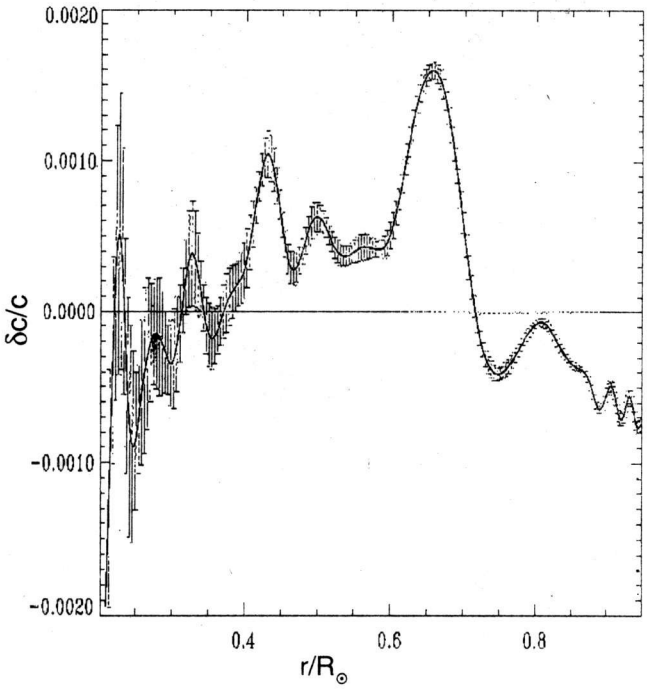

Fig. 1.10 : Relative difference in sound speed between the sun and the reference model along with the estimated errors. The frequencies are taken from GONG month-7 and the error bars show the 2-sigma errors.

Effect of Opacity Modifications on Solar Oscillations

The difference between the frequencies produced by opacity modifications and those obtained recently from GONG observations is found to be very small. These frequency differences are inverted using asymptotic inversion technique to obtain the sound speed in the solar interior **(Fig. 1.10)**.

(S.C. Tripathy, H.M. Antia and J. Christensen-Dalsgaard)

Seismic probing of the Solar interior using GONG Frequencies

The Canuto-Mazzitelli formulation for calculating the convective flux is found to agree with observations than the mixing-length model. Inversion results, using models with MHD and OPAL equation of state, show that the OPAL equation of state better describes the solar material.

(S.C. Tripathy, H.M. Antia, F. Hill and A. Ambastha)

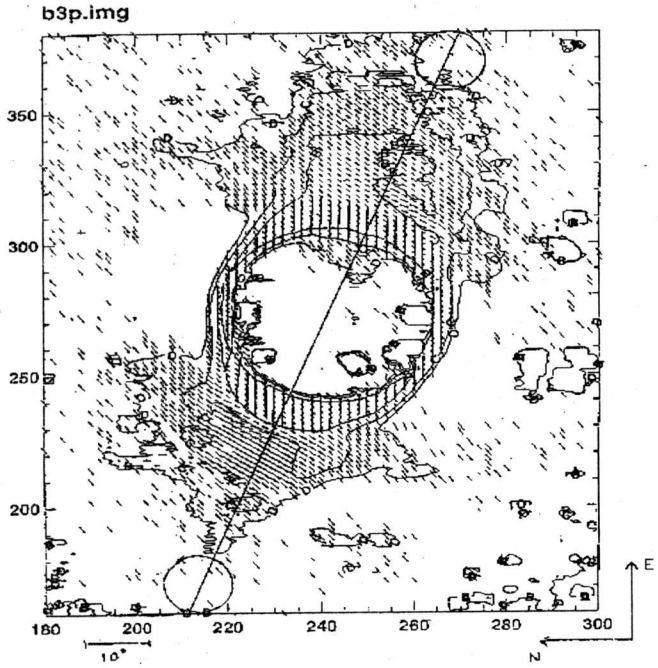

Fig. 1.11 : Polarisation map of the corona October 24, 1995 from observation of Total Solar Eclipse from Kalpi (U.P.). The contours correspond to the degree of linear polarisation and the line-segments represent the magnitude and direction. The hatched region is saturated inner corona. The two small circles along the equatorial plane are the expected positions of the dust ring.

Flare Productive Emerging Flux Regions

Longitudinal magnetic fields and H-alpha observations are good combination for studying the emerging flux regions, changes in magnetic field gradient, and the flare activity. We have taken up such a study of Active Region NOAA 7843 using the data obtained from the USO videomagnetograph (VMG), which provides near-simultaneous longitudinal magnetic field, continuum and H-alpha images.

(Shibu Mathew and A. Bhatnagar)

Search for Circum-Solar Dust Ring

A circum-solar dust ring, consisting of micron-sized particles from comets and asteroids, is believed to be situated at 4 solar radii. The past observations suggest that the ring might be temporally variable, with higher probability of detecting it during the minimum phase of solar activity cycle. The total solar eclipse of October 24, 1995, provided opportunity to test this hypothesis. In collaboration with the Space Applications Centre (SAC), Ahmedabad, an experiment was designed at USO to photograph the circum-solar region up to 5 solar radii. The experiment was successfully performed at Kalpi, UP. The polarisation maps of the corona do not show any significant peak attributable to the ring feature **(Fig.1.11)**.

(Debi Prasad C., A. Ambastha and SK Gupta)

Chromospheric Doppler Velocities, Photospheric Magnetic Fields, and the Flare productivity in Super Active Region NOAA 6555

We have found a remarkable correspondence between the large scale Doppler flow patterns at the transition region and the magnetic polarity in the photosphere. Study of the super active region NOAA 6555 shows that there exists a velocity reversal line in the chromosphere over the photospheric magnetic neutral line. Where as the velocity reversal line and the magnetic neutral lines are found to be parallel in the relatively quiet locations, they are perpendicular to each other at the location of the large X-class flares.

(Debi Prasad C., A. Ambastha and S. C. Tripathy)

A New Relationship between the Solar and Geomagnetic Activities

The annual index of geomagnetic activity, "aa", is found to vary in consonance with the annual solar proton flux at energy >10MeV **(Fig. 1.12)**. It reveals an empirical relationship useful to predict the aa index. On the basis of geomagnetic activity during the descending phase of the preceding cycle, the annual mean of the maximum sunspot number in Cycle 23 is predicted to be 172.8.

(Rajmal Jain).

Correlation between Sunspots and Rainfall in Udaipur Sub-region

The cross-correlation between 102 years rainfall data of Udaipur sub-region and sunspots shows periodicities of about 11 year or its multiples. A period of

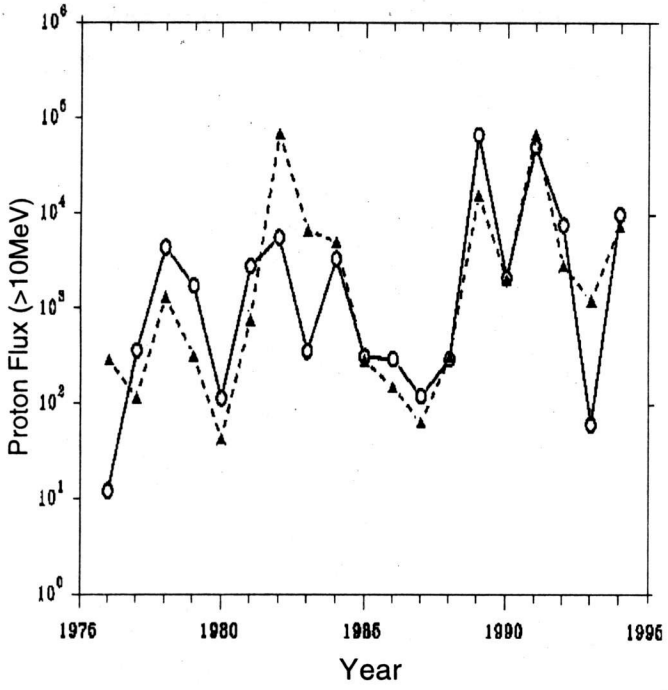

Fig. 1.12 : Variation of Total annual proton flux (in pfu) at >10MeV energies (solid line) and geomagnetic activity annual aa index (dotted line) over the period 1976 to 1994.

about 27% is found to deviate from the normal rains in the form of flood, excess and deficit of rains in Udaipur subtropical region.

(Rajmal Jain and S. C. Tripathy)

Solar Observations from USO on TSE Day of 24 October, 1995

Chromospheric and photospheric observations were taken from USO on October 24,1995, in partial eclipse phases. The pictures are being digitised to determine the correlation between percentage obscuration of the solar disk and the variation in the flux at various wavelengths with the aim of probing the dynamics of Earth's atmosphere.

(Rajmal Jain and Shibu K. Mathew)

Large Scale Phenomena in Comet Hyakutake

Comet Hyakutake was extensively observed from USO during 21-26 March 1996. The study was aimed at understanding the large scale phenomena of the cometary dust and the interaction of the comet's plasma tail with the solar wind. We have recorded a part of the disconnection event (DE) on 24 March 1996. The images taken through different polaroid filter orientations are being studied to understand the dust property of the cometary tail.

(A. Bhatnagar, Debi Prasad C., A. Ambastha, S.C. Tripathy and SK Gupta)

ASTROPHYSICS

A WKB Formalism for Multicomponent Fields and its Application to Gravitational and Sound Waves in Perfect Fluids

Reviewing the WKB method for multicomponent fields obeying hyperbolic linear partial differential equations we derive a necessary and sufficient condition for the formalism to provide transport equations. We then apply the method to linearised perturbations of perfect fluid solutions to Einstein's equations and show that the gravitational and sound wave modes satisfy this condition whereas a zero frequency, non-propagating matter mode does not. We derive the transport equations for the wave amplitudes in leading order and show that they exhibit in particular the influence of background curvature on the propagation of gravitational waves. (This work was done in collaboration with Prof. J. Ehlers, Max Planck Instiutut fur Astrophysik).

(A.R. Prasanna)

Astrophysical Signals of P and T Violations by Gravity

We study the observational consequences of the leading order P and T violating gauge invariant graviton-photon interactions through non-minimal couplings. Such interactions give rise to gravitational birefringence - the velocity of light signals depends upon their polarisation, which is absent in pure Einsteinian gravity. Using experimentally established limits on the differential time delay in the radio signals from pulsars we put constraints on the magnitude of such couplings.

(A.R. Prasanna and S. Mohanty)

Radial Pulsation Frequencies of Slowly Rotating Neutron Stars

We study the radial pulsation frequencies of slowly rotating neutron stars in the general relativistic formalism using realistic equations of state. It is found that the pulsation frequencies are always an increasing function of rotation rate. However, the increasing rate of frequency does depend upon the nature of equations of state.

(P.K. Sahu and A.R. Prasanna)

Centrifugal Force in Circular Polar and Oblique Orbits off the Equatorial Plane around a Rotating Compact Object

Centrifugal force reversal in circular orbits on the equatorial plane coincides with the unstable photon orbit for static spacetimes. However, in the case of stationary axisymmetric spacetime the reversal occurs somewhere in between the pro and retrograde photon orbits. However, in the case of polar orbits (passing through $\theta = 0$ and π) again the reversal radius matches with the photon orbit. The discussion is being extended to cover the oblique orbits wherein the meridional and azimuthal velocity would change continuously.

(A.R. Prasanna and Sai Iyer)

Centrifugal Reversal for Slowly Rotating Compact Objects

Earlier we have discussed the centrifugal reversal and the ensuing ellipticity maximum for a slowly rotating ultra compact objects with constant density using Hartle-Thorne solution. We are extending these discussions to the case of configurations with different equations of state so that the analysis would directly relate the structure and shape of the compact object to the equation of state of the matter distribution inside the object.

(Anshu Gupta, Sai Iyer and A.R. Prasanna)

Structure of Electromagnetic Fields Inside a Slowly Rotating Compact Object

As the nature of generation and sustenance of magnetic fields inside a neutron star is still an enigmatic problem, we are studying the nature of the poloidal magnetic field in a slowly rotating compact object within the framework of general relativity which relates both the gravitational and electromagnetic fields through coupled Einstein-Maxwell equations. As the nature of the field at the centre cannot be assumed, we follow a procedure wherein the coupled equations are integrated numerically from the boundary towards the centre, since the nature of the field outside the star is known.

(A.R. Prasanna and P.K. Sahu)

Cylindrically Symmetric Solutions in Einstein-Cartan Theory

Motivated by the recent surge of interest in cosmic strings, we search for exact cylindrically symmetric interior and exterior solutions of the Einstein-Cartan theory, using a phenomenological ansatz for the spin fluid and formulate the Arkuszewski-Kopazynski-Ponomariev junction conditions at the boundary. With a cylindrically symmetric ansatz for metric and torsion, we arrive at three second order and one first order coupled ordinary differential equation which can be integrated under special circumstances. (This work was done in collaboration with R.R. Puntigam and F.W. Hehl of University of Koln).

(A.R. Prasanna)

Gravitational Radiation

The coalescence of two compact objects (neutron stars or black holes) is an important source of gravitational radiation. The detection and study of this radiation requires the use of very accurate templates. We have studied gravitational radiation reaction in such binary systems to 2PN order ($O(v/c)^4$), corresponding to 4.5PN order ($O(v/c)^9$) corrections to Newtonian motion. The equations of motion so derived are valid for general binary orbits and for a class of coordinate gauges. This work was done in collaboration with B.R. Iyer and Gopakumar of Raman Research Institute, Bangalore.

(Sai Iyer)

Axisymmetric Magnetohydrodynamic Equilibrium around a Magnetized Compact Object

We have studied the equilibrium structure of a pressure-supported magnetized fluid disk around a compact object without invoking any thin disk approximations. In this work, we have used the basic set of covariant form of general relativistic magnetohydrodynamic (MHD) equations that govern the flow of a stationary (i.e. $\partial_t \equiv 0$) axisymmetric (i.e. $\partial_\varphi \equiv 0$), pressure-supported fluid disk in a state of azimuthal motion only. We have obtained two classes of solutions : (i) when the MHD flow velocity becomes quasi-Keplerian in the flat space limit and (ii) when the MHD flow velocity becomes rigid rotation type (with the star) in the flat space limit. Such solutions may be useful in constructing a model of a pulsar magnetosphere with general realtivistic effect. Such models may be useful in studying the effects of the plasma on the basic electromagnetic processes occuring in the vicinity of the compact object. Furthermore, these solutions, in the Newtonian limit, can be used to construct an analytical model for the magnetic torque exerted by the disk on the central compact object.

(D. Banerjee, J. R. Bhatt, A. C. Das, and A. R. Prasanna)

ATOMIC AND MOLECULAR PHYSICS

Addition Theorems for Solid Harmonics and the Second Born Amplitudes

A simple but novel method is described to prove the addition theorems for solid harmonics. This method gives new insight into the richness of the contents of the expansions of plane waves and the Coulomb potential between two point particles in terms of complete set of spherical harmonics. As a concrete application of the addition theorem for the regular solid harmonic, an integral containing the spherical harmonic Y^m_l which frequently occurs in the second Born term is evaluated in a compact form.

(Sima Chakrabarti and D.P. Dewangan)

Transitions between Excited-States of Hydrogen-like Ions in a Multiple Scattering Model

This is an ongoing project. The main challenge in the theoretical study of excited-state to excited-state (nlm $\rightarrow$ n'l'm') transitions arises because of the need to include a large number of important closely spaced atomic states lying near the initial and final states. In the first stage of our investigation, we used the Coulomb-Glauber (CG) method. It is widely believed that the CG method predicts the (summed over angular momentum states) n $\rightarrow$ n' cross section reasonably well but is not as good for the state-to-state (nlm $\rightarrow$ n'l'm') cross section because of the selection rule that $(-1)^{l+l'+m+m'}$ must be even for nonvanishing CG amplitude. To compute the state-to-state (nlm $\rightarrow$ n'l'm') cross sections more realistically, we have developed a multiple scattering model in which the effects of multiple

scattering is described by using two on-shell Coulomb wave functions in such a way that the correct boundary conditions are satisfied. This model goes beyond the Glauber method in the sense that unlike the latter method, it contains both real and imaginary parts of the second and all higher-order Born terms. The price to pay for this refinement is that the integral expression of the transition amplitude of the multiple scattering model used in the numerical work is rather mathematically involved with branch point singularities and its computation is challenging and tricky. We have been able to develop the computer code for ns $\rightarrow$ n's transition and have found that even for low-lying H(1s) $\rightarrow$ H(2s) transition, it provides satisfactory agreement with the only available experimental results at 54.4 eV by electron impact. Now we are concentrating on transitions involving changes in the angular momentum states.

(D.P. Dewangan and Sima Chakrabarti)

Asymptotic Cross Section for Pair Production in Relativistic Atomic Collisions

As an alternative mechanism for bound-free electron-positron pair production, the transfer of a negative energy electron in the Coulomb field of the target nucleus to a bound state of the projective is considered, supplementing the usually adopted view that an electron is excited from a negative energy state to a bound state of the same atom. In this paper, we examine in detail the post form as well as the prior form distorted wave Born approximation and pay particular attention to the asymptotic behaviour of the cross section. It is found that for both the forms, the total cross section increases with the projective Lorentz factor γ as γ^2 in contrast to the lnγ dependence following from the excitation like processes. (This work is being carried out in collaboration with Prof. J. Eichler of Hahn-Meitner-Institut, Berlin, Germany).

(D.P. Dewangan)

For experimental activities refer to p. 65 under Planetary Atmospheres and Aeronomy.

HIGH ENERGY PHYSICS

Automatic CP Invariance

CP appears to be a symmetry of nature to a very good approximation. Such invariance does not normally follow from the gauge invariance of the underlying theory. We have proposed a mechanism in which the gauge symmetries of the theory automatically leads to CP invariance of the renormalizable Lagrangian. The non-renormalizable, higher dimensional terms lead to its violation required on phenomenological grounds.

(A. Dutta and A. S. Joshipura)

Astrophysical Signatures of R Parity Violation

Super symmetric version of the standard model is required to be invariant under a discrete symmetry called R symmetry. Gravitational interactions can violate this symmetry. We show that even very mild violation of this symmetry induced by gravity conflicts with the astrophysical signatures such as diffuse radiation background. We discuss possible schemes which lead to a suppressed violation of R parity and discuss their cosmological consequences. (This work is done in collaboration with V. Berezinsky and J.W.F. Valle).

(A. S. Joshipura)

QGP in Early Universe

At and before micro-second epoch of the expanding universe the Quark Gluon Plasma (QGP) is expected to play a dominant role. So far this has been ignored in the theory of early cosmology for want of a reliable equation of state other than that of extreme relativistic matter. The relativistic harmonic models for quark and gluon, on the other hand, give a unique equation of state for QGP, which implies the energy density/pressure go as a seventh power of intrinsic temperature of QGP. The Einstein equations with corresponding Friedman-Walker metric then give that the scale factor (a) goes as $t^{4/7}$ instead of $t^{1/2}$ as in the case of radiation dominated universe. In the mixed phase state of the universe the radiation still dominates and $a \sim t^{1/2}$. More investigations are needed in inhomogeneous universe models including the first order

phase transition of QGP to hadronic matter resulting probably in a mild inflation.

(S.B. Khadkikar and S. Mohanty)

Hadronic Correlators and Condensate Fluctuations in QCD Vacuum

In this work, we use phenomenological results of equal time, point to point spatial ground state correlation functions of hadronic currents to guide us towards a "true" structure of QCD vacuum. We construct an explicit variational ansatz for QCD vacuum with quark and gluon condensates. It is found that the ansatz is not adequate to explain the observations in the pseudoscalar channel.

We therefore suggest a more complicated ground state of QCD which includes a non-vanishing irreducible four point structure. Such a structure is parameterized from phenomenological constraints. The parameters are chosen so that our correlation functions are similar to those obtained from phenomenology. The resulting normalized hadron correlators are plotted verses distance x (in fm) in **Fig. 2.1**. Our results (solid curves) are comparable with empirical results determined by dispersion analysis of experimental data (long dashed), lattice calculations (dotted) and instanton model (dot-dashed). We fit our results to phenomenologically motivated forms for correlators parameterized in terms of mass, coupling and threshold of the corresponding particle. These parameters also compare well with those in other models.

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

Decay-Lepton Distributions in $e^+e^- \to t\bar{t}$ and Dipole Couplings of the Top Quark

Complete analytic expression was obtained for the charged lepton asymmetry arising from the decay of a top quark or top antiquark in the process of top pair production in electron-positron at future linear colliders. The effects of possible CP-violating dipole couplings of $t\bar{t}$ to virtual γ and Z as well longitudinal beam polarization were included. These expressions were used to derive very simple asymmetries of the decay leptons, which could be used to study the dipole couplings. These asymmetries are special in that they do not require the full determination of the direction of the top or antitop. Simultaneous limits on dipole couplings attainable at linear colliders with polarized beams were estimated.

(P. Poulose and S.D. Rindani)

Helicity-Flip Bremsstrahlung and the Measurement of CP-violating Form Factors in Polarized e^+e^- Collisions

Certain CP-odd correlations were earlier shown to give higher sensitivities to top quark and tau lepton electric and weak dipole form factors in the process of e^+e^- annihilation using longitudinally polarized beams. However, in the practical case where only the electron beam can be polarized, there would be a potential background from wrong-helicity contributions which arise due to the process of initial state radiation of a hard collinear photon. The background from these helicity-flip contributions was estimated using the technique developed by Falk and Sehgal. It was found that with statistics available in foreseeable experiments, the background would negligible as compared to the statistical fluctuations. (This work was done in collaboration with B. Ananthanarayan of University of Lausanne).

(S.D. Rindani)

Baryogenesis

At present we see around us mostly baryons and rarely some antibaryons. This could be explained in grand unified theories, but in recent times it has been pointed out that during the electroweak symmetry breaking there can also be large baryon number violation, which can erase the primordial baryogenesis. Since then an interesting idea has been proposed where in the early universe lepton asymmetry is generated, which during the electroweak phase transition gets converted to baryon asymmetry. We (with M. Flanz and E. A. Paschos) pointed out that it is possible to have a new CP-violating effect, whose contribution to the generation of lepton asymmetry in these models is larger than the one discussed in the literature. We (with E.A. Paschos and H. So) also pointed out that in E_6 grand unified theories baryon and lepton number assignments are not unique and this can have interesting consequences in the problem of baryogenesis.

(U. Sarkar)

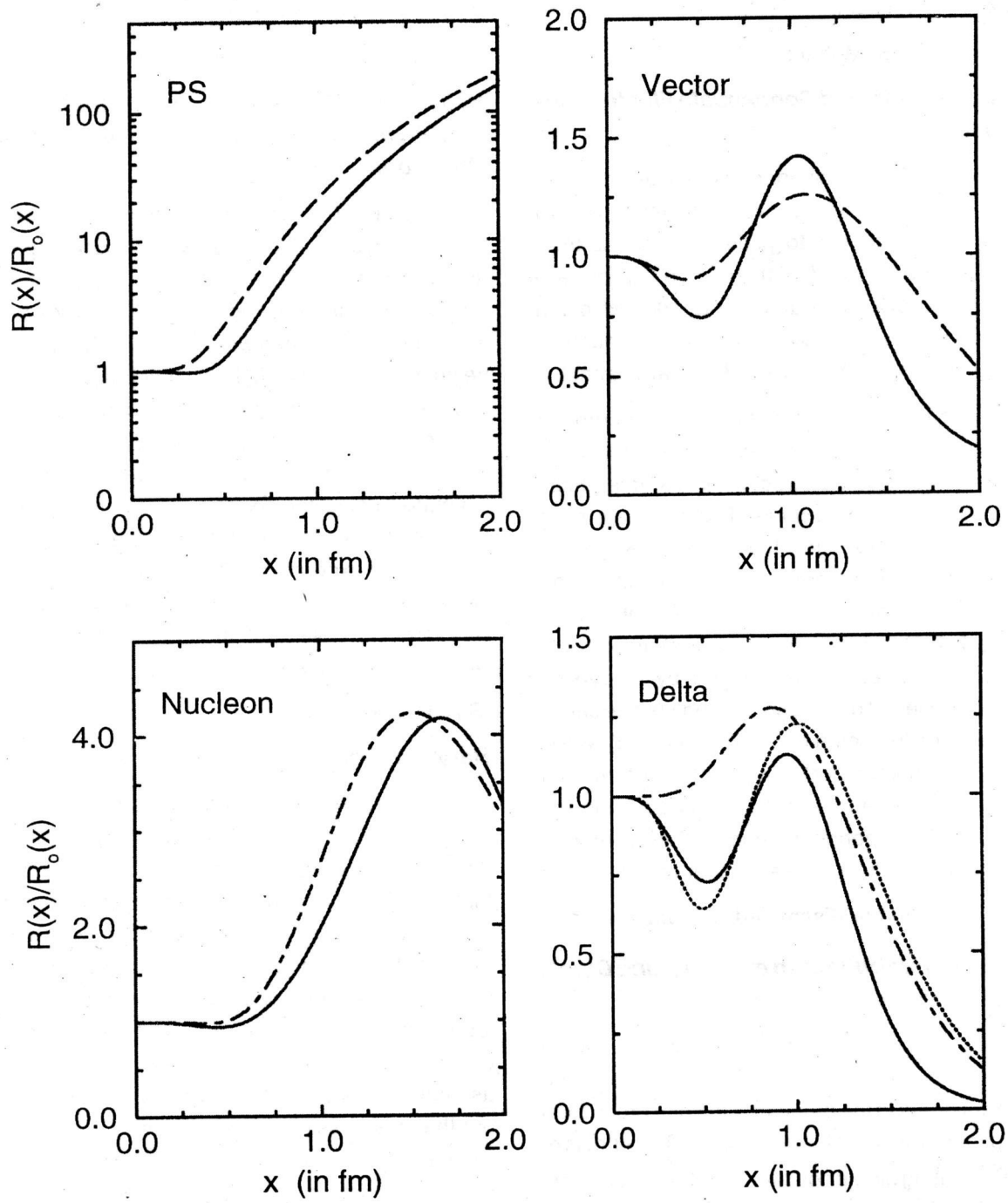

Fig. 2.1 : The normalized hadron correlation functions R(x) / R_o(x) vs. distance x (in fm). Our results are given by the solid curves. The empirical results determined by dispersion analysis of experimental data are shown by long dashed lines. The results from lattice calculations and instanton model are denoted by dotted and dot-dashed lines respectively.

LEP Constraints on GUTs

The precise measurement of the gauge coupling constants of the standard electroweak model in the large electron-positron collider experiment puts severe constraints on grand unified theories. We have shown that several of these constraints may be evaded if gravity changes the boundary conditions near the grand unification scale. This work was done in collaboration with A. Datta and S. Pakvasa.

(U. Sarkar)

Gravitational Cerenkov Radiation and the Detection of Cosmic Strings

The background gravitational field inside a cosmic string core acts as a medium of refractive index greater than one for the propagating photons: Charged particles trapped in the core of cosmic rays emit radiation by the gravitational Cerenkov process and the characteristic spectrum of such radiation can be used to search for cosmic strings by optical or radio telescopes.

(A. Gupta, M.K. Samal and S. Mohanty)

Transition Radiation as a Mechanism for Supernova Shock Revival

The transition radiation by neutrinos with a non-zero magnetic moment is proposed as a mechanism for giving the necessary energy to the supernova shock front to blow out of the supernova.

(S. Mohanty and S. Sahu)

Thermalization in the Quark-Gluon Plasma

One of the most important problems in relativistic heavy-ion collisions is that of thermalization of the collision products. At relativistic energies nuclear collision can be visualized as leaving highly exicited, dense coloured particles system in the central collision region which is not in thermal equilibrium. The system then comes to equilibrium due to interaction among coloured particles. We have emphasized the role of non-pertubative collective effects in the thermalization of such system. In particular, using the equation of motion of a classical SU(2) coloured particle, we have developed 1+1 dimensional numerical code to simulate the quark-gluon plasma. We find that the chaotic behaviour introduced by the non-abelian plasma oscillations can play a significant role in the thermalization of the quark-gluon plasma compared to the other collisional mechanisms. (This work was done in collaboration with P.K. Kaw and Sudip Sengupta of IPR).

(J.R. Bhatt and J.C. Parikh)

NUCLEAR PHYSICS

Extended SU(3) Bose and Bose-Fermi Dynamical Symmetries and their Applications

The Bose SU(3) dynamical symmetry of the interacting boson model (IBM) is appropriate for even-even heavy deformed nuclei. The SU(3) group appears in various extended versions of IBM; for example in the proton-neutron IBM that distinguishes proton (π) and neutron (ν) bosons, the sdgIBM that includes hexadecupole g bosons, the interacting boson - n-fermion model (IBF^{n}M) where n-fermions are coupled to IBM core etc. Several SU(3) based Bose and Bose-Fermi dynamical symmetry group chains in these extended models are identified, developed and applied. They are: (i) a basis and hamiltonian within the sdgIBM [U(6) $\supset$ SU(3)] $\otimes$ U(9) limit that generate the (C_4 symmetry related) $\Delta L = 4$ staggering in even-even nuclei is identified and this staggering is seen in some super-deformed bands; (ii) asymptotic limit expressions for B(E2)'s and B(M1)'s are derived in the IBFM (n=1) SU(3) limit and using them ^{187}Os and ^{175}Re data are analyzed successfully; (iii) IBF^{2}M SU(3) $\otimes$ U(2j+1) limit appropriate for certain configurations in odd-odd nuclei is developed and this limit generates doubly decoupled bands such as those seen in ^{176}Re nucleus; (iv) recently observed M1 distributions in ^{163}Dy and ^{157}Gd nuclei are described using the proton-neutron Bose-Fermi SU(3) symmetry chains we developed in the last two years. All these new studies establish that the Bose and Bose-Fermi SU(3) dynamical symmetries apply much more widely than that envisaged before. (This work was done in collaboration with Y.D. Devi and U.D. Pramanik).

(V.K.B. Kota)

Strength Fluctuations and Effective Dimensionality

The embedded Gaussian orthogonal ensemble (EGOE) of random matrices gives a form for the secular variation of strengths (and the corresponding strength densities) generated by the action of a transition operator on nuclear eigen states in the chaotic domain; the strength densities take a bivariate Gaussian with small corrections. Combining the secular variation with the Porter-Thomas form for the local fluctuations in strengths, an integral expression is derived for the mean square deviation of the strength sum originating at a given energy from its smooth counterpart. For the effective dimensionality d(E) (the number of eigen states excited by the transition operator by acting on the eigen state at energy E) defined by it, using the bivariate Gaussian form for strength densities, a compact formula is derived. Using shell model calculations the calculated d(E) is verified to fit very well the shell model root mean square deviations in the strength sums. The d(E) defined via fluctuations in strength sums is similar to the measure 'number of principal components (NPC)' that is being used recently in the analysis of chaotic eigen states of quantum systems. This similarity and its consequences are being investigated.

(V.K.B. Kota)

PLASMA PHYSICS

Hénon-Heiles Hamiltonian for Coupled Upper-Hybrid and Magnetoacoustic Waves

Amplitude modulated, high-frequency upper-hybrid waves coupled to the low-frequency magnetoacoustic waves in a magnetized electron-ion plasma are known to be governed by a Schrödinger-like equation wherein the "potential" is given in terms of the associated low-frequency number density perturbations. For finite amplitudes, the latter are shown to be governed by a nonlinear, driven equation of the Boussinesq type. In the present work, we have demonstrated that for stationary propagation the coupled mode equations for the upper-hybrid and the magnetoacoustic waves with negative group dispersion can be exactly derived from the generalized Hénon-Heiles Hamiltonian and thereby have explicitly obtained three sets of parameter regimes wherein the coupled stationary waves are exactly integrable **(Figures 2.2 and**

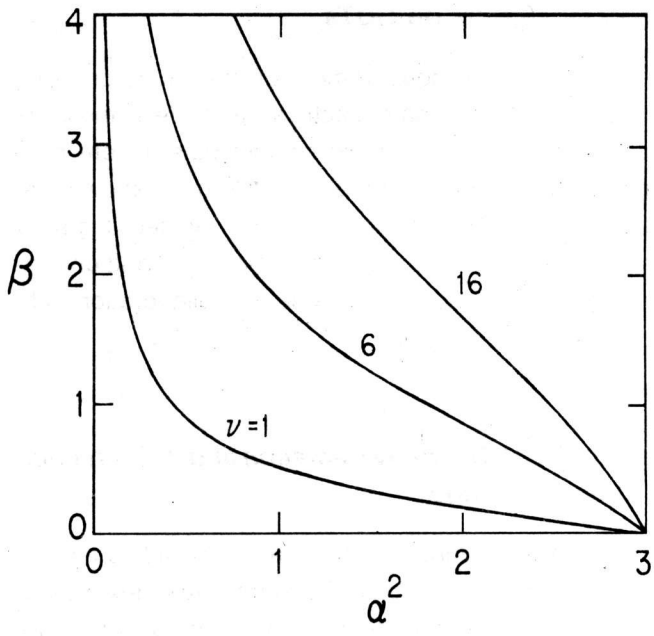

Fig. 2.2 : Parameter regimes for the integrability of stationary, coupled upper-hybrid and magnetoacoustic waves with negative group dispersion in a magnetized plasma. For ν = 6, the coupled waves are completely integrable for any values of the Mach number (M) and the nonlinear frequency shift parameter (L). For ν =1 and 16, the latter parameter are obtained in Figure 2.

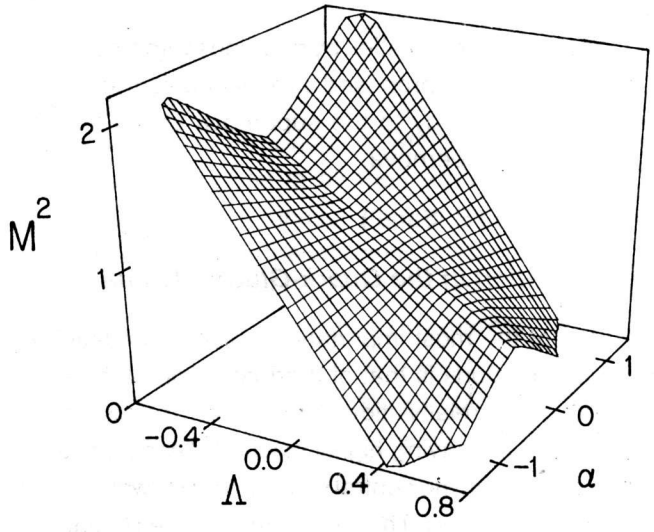

Fig. 2.3 : Integrable parameter regime for ϕ = 1 in the (M,L,α) parameter space for negative group dispersion of the upper-hybrid waves. Qualitatively similar regime exists for the ν =16 case also.

2.3). For the case when the group dispersion is positive, the coupled equations lead to a novel kind of Hamiltonian where the kinetic energy is not positive definite. Attempts are being made to explicitly obtain the parameter regimes for the known integrable cases.

(N.N. Rao)

Coulomb Crystallization in Colloidal Plasmas with Streaming Ions and Dust Grains

The test charge potential of a dust particle in dusty plasmas with equilibrium ion and dust particle streaming has been investigated using the kinetic theory. Our results show that besides the Debye screening potential, there appear far-field and non-Coulombian potentials. The latter could be attractive in nature and, hence, can be responsible for bringing like particles together so that microscopic Coulomb crystallization occurs in dusty plasmas. The physical mechanism for the crystallization process involves the polarization of the medium produced by the test particle by attracting positive ions that are involved in the collective modes such as the dust-acoustic waves. Similar to the Cooper pairing, the excess positive ions attract the neighbouring dust grains with a force that is strong when test particle velocity is close to the Doppler shifted phase velocity of the dust-acoustic waves. In such a situation there appears an oscillatory wave potential behind the test grain resulting in quasi-lattice structures. (This work was carried out in collaboration with Prof. P.K. Shukla).

(N.N. Rao)

Charging of Dust Particles by a Plasma

Earlier we had carried out certain preliminary experiments aimed at charging of dust particles by introducing them in the path of a flowing plasma. The experiments had given clear indications that the dust particles accumulate negative charges resulting in a depletion of electrons in the plasma. Encouraged by these results we are setting up a new experimental device **(Fig. 2.4)** to carry out the investigation of the phenomenon in greater detail.

A steady state Argon plasma flow, produced with the help of a Reflex discharge Penning type of source, is injected into an SS vacuum chamber. The axial magnetic field both in the gun region and the SS chamber are produced by a set of seven coils. The magnetic field in the system is sufficient for the electrons to be considered

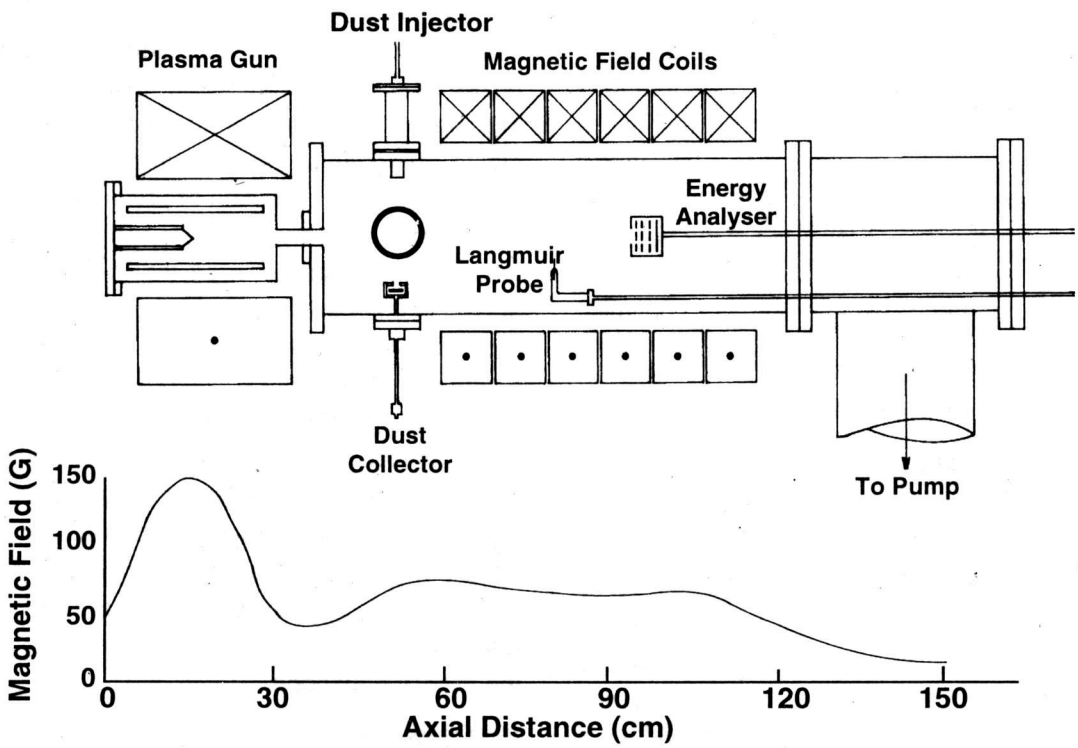

Fig. 2.4 : Schematic of the Dusty Plasma device

magnetised whereas the ions are not. The plasma parameters are measured with the help of electrostatic probes, movable both axially and across the diameter of the plasma column. A multigrid electrostatic analyser has been designed for obtaining the energy spectrum of both the electrons and ions. About one mg. of the dust, a fine powder of Al_2O_3 is injected vertically in the path of the plasma about 11 cms away from the point of injection of the plasma into the SS chamber with the help of a specially designed dust injector. Right below the duster at the bottom of the chamber is placed an SS disk collector, for estimating the extent of charging of the dust during its passage through the plasma. Another identical disk mounted on a trolley, movable along the length of the system is used for registering of charged dust if any at points away from the dust injection zone.

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

Particle Confinement in Magnetic Mirrors

The aim of the experiment is to study the particle confinement properties of the mirror maintaining the scale length and height of the mirrors constant and vary the width of the magnetic field peaks. The electron gun is situated outside the mirror and the initial pitch angle of the electrons at the outlet of the gun is so chosen that they would not normally be able to get through the first mirror itself. A short positive pulse is applied to a cylindrical anode, placed coaxially in the region of the first mirror, which would result in the overall lowering of the height of the barrier and temporarily permit the entry of the beam into the mirror. Experiments are in progress to optimise the beam injection into the mirror.

(Chetan Joshi, R.K.Varma and A.M.Punithavelu)

NON-LINEAR DYNAMICS

Two Point Expansions and Perturbation Theory

The Taylor series, which forms the basis of all Perturbation Theory, is an expansion which uses the values of a function and its derivatives at a point to approximate the function in a neighbourhood of the point. We have considered a generalization, where the values of the function and its derivatives at two or more points is used to derive a polynomial approximation. We have derived the method of calculating the coefficients of the approximating polynomial for arbitrary functions. The resulting polynomials have been used to calculate the second invariant for a Classical Mechanical Hamiltonian system and to calculate the lowest energy eigenvalue for a Quantum Mechanical system. In the first case, the time derivative of the resulting invariant is computed numerically and compared with that resulting from ordinary perturbation theory. It is observed that the two point theory is superior to the Taylor series theory, especially far away from the point around which the Taylor series expansion is made. The Quantum Theory results are compared with a numerically evaluated energy; once again the two point results are superior to the Taylor series result, especially far away from the point around which the Taylor series is expanded.

(B.R. Sitaram)

Invariants from Painleve Series

The Painleve test, and its variant the weak Painleve test, have been used for many years as a test for integrability of Hamiltonian systems. We have shown that if the Hamiltonian under consideration is polynomial in the phase space coordinates, the resulting Painleve series has the property that it is analytical in the arbitrary constants. This enables us to rewrite the Painleve series in the form of an implicit function of phase space coordinates, time and the arbitrary constants, with the property that the functions are analytic in all their arguments. We then appeal to the Implicit function theorem to conclude that it is possible to express the arbitrary constants as analytical functions of the phase space coordinates. This provides us with an algorithm to determine invariants for all polynomial Hamiltonian systems which pass the Painleve test. The method has been successfully applied to 1 degree of freedom systems and to a non-Hamiltonian systems with three phase space coordinates. Attempts are underway to look at systems with two degrees of freedom, where the major problem is the complexity of the problem of solving the implicit equations.

(B.R. Sitaram)

Accuracy of Semiclassical Trace Formulas

Using quantum maps we studied the accuracy of semiclassical trace formulas. The role of chaos in improving the semiclassical accuracy, in some systems, is demonstrated quantitatively. However, our study of the standard map cautions that this may not be most general. While studying a sawtooth map we demonstrated the rather remarkable fact that at the level of the time one trace even in the presence of fixed points on singularities the trace formula may be exact, and in any case has no logarithmic divergences observed for the quantum bakers map. Evaluating certain incomplete Gauss sums exactly, we provide the first example of a quantized chaotic system whose trace is not the semiclassical trace and whose correction terms are explicitly available. As a by product we introduced fantastic periodic curves akin to curlicues.

(A. Lakshminarayan)

Local Scaling in Homogeneous Hamiltonian Systems

We studied the local scaling properties associated with straight line periodic orbits in homogeneous Hamiltonian systems, whose stability undergoes repeated oscillations as a function of one parameter. We gave strong evidence of local scaling of the Poincaré section with exponents depending simply on the degree of homogeneity of the potential. Further work to understand this phenomena for two dimensional systems and extension to higher dimensions is in progress.

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

Exponential Localization and Entropy Oscillations

We have shown that in smooth two dimensional coupled an harmonic oscillator systems eigen functions scarred by the simplest periodic orbit exhibits exponential localization in the unperturbed basis which have universal characteristics. These states exhibit entropy oscillations which correlate with the stability oscillations of the underlying periodic orbit.

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

Time Evolving States in Quantum Chaos

Time evolving states are studied with a view to understand and study several phenomena when the quantum system has a classically chaotic limit. We study smooth two dimensional anharmonic oscillators with known classical nonlinear behaviours. In particular, we study the statistical properties of these states and relate them to evolution due to a random matrix emsemble, as was done by us earlier using quantum maps. We will also use these time evolved states to understand if Bohmian mechanics can be used to define quantum chaos.

(V.B. Sheorey and A. Lakshminarayan)

NEURAL NETWORKS

Simulation of Characteristics and ANN Modelling of EEG Time Series

The observed EEG time series data of a normal individual with eyes closed is analyzed and modelled. It is shown that important characteristics of the EEG could be reproduced if filtered Gaussian noise was subjected to an exponential fall in the power spectrum. The studies also imply that the EEG signal is weakly chaotic with high embedding dimension. The observed data can also be very well fitted by an artificial neural network model without any hidden neuron, suggesting that the system is essentially linear and deterministic. **Fig. 2. 5** shows the excellent agreement between the ANN model and the test data set.

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

Artificial Neural Network (ANN)

The Work is being carried out in the area of back propagation training of multilayered perceptrons, unsupervised and supervised learning, classification, pattern recognition etc. A re-configurable neural network simulator is developed using "C++". The simulator uses a concept of software connector to built hybrid type ANN. This simulator is being used for digital filter design, speech recognition, character recognition etc. **Fig.2.6** shows the results of a hand written character recognition system. For the application of neural network in dedicated real time systems digital signal processors are used. A DSP based

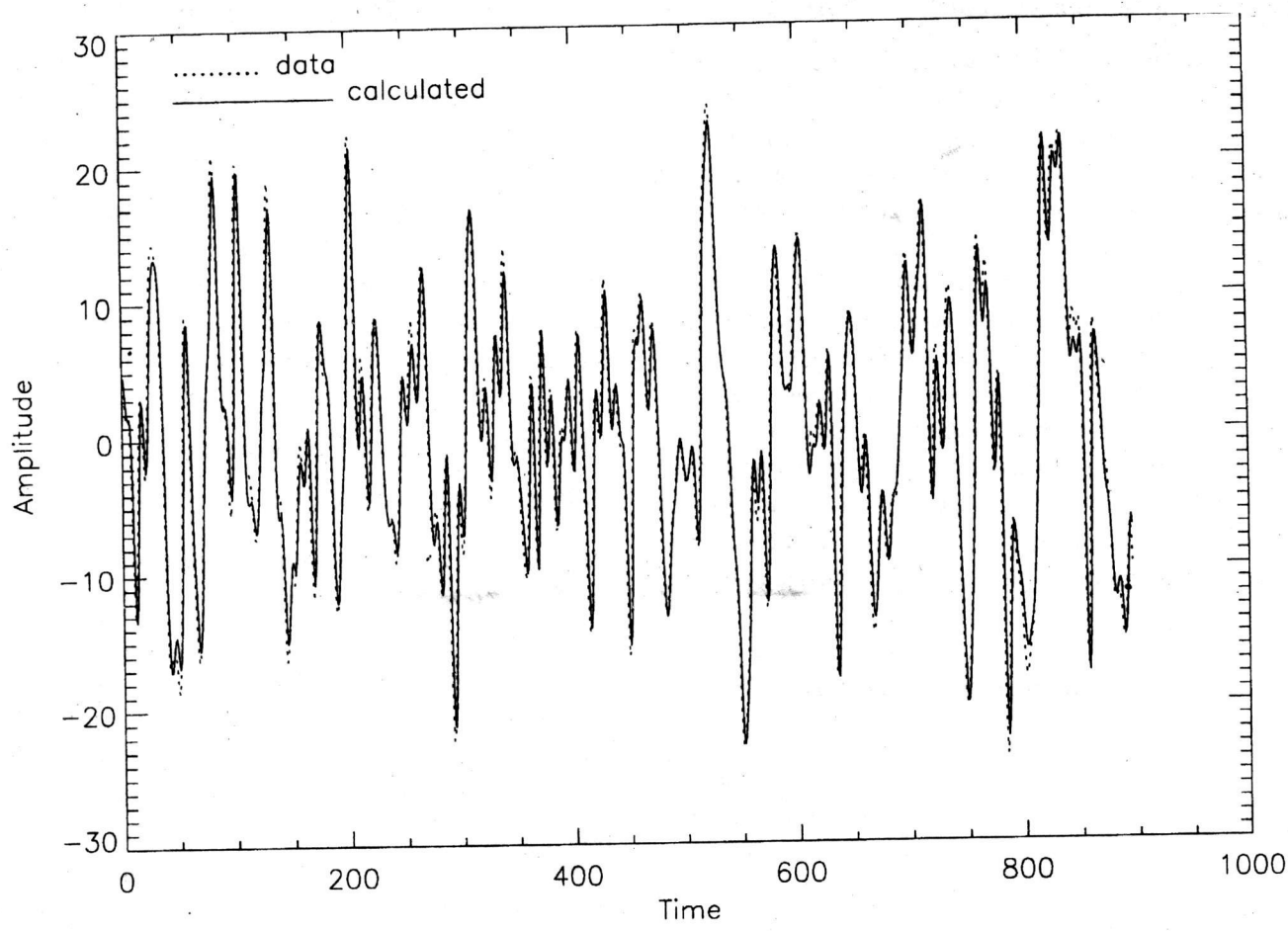

Fig. 2.5 : Observed and calculated values of EEG test data set using ANN.

Back propagation algorithm has been developed. The novel activation function has been developed which produces bounded output and is of the form : Yn=Yb+Yb*Xn/(Gn+abs(Xn)) where Xn is the analog output in the range 2^{-15} to 2^{+15}. The main difference in the activation function comes in the backward pass for modifying the weights which takes the form : Yi=yi*(Yjmax-Yj), Gn is the co-efficient of activation function which determines gradient. This algorithm involves the training or modification of the activation function coefficient. The error convergence rate is found to be better than the conventional B. P. algorithm for analog and digital problems.

(H.S.Majumdar)

Self Organized Multilayered Neural Networks

Feed forward type networks needs supervised learning to train the network; self organized networks on the other hand are used in application of image classification, speech recognition, language translation etc. An computer algorithm has been developed to train the multilayered feed forward type network in both supervised and unsupervised mode. Unsupervised learning is achieved by maximum output and de-clustering the crowded classes simultaneously. This algorithm can force any output to learn a desired class using supervised learning like B. P. The population of each class can be controlled with greater flexibility. Such a network was used to classify ASCII character set in 32 classes. The outputs can be

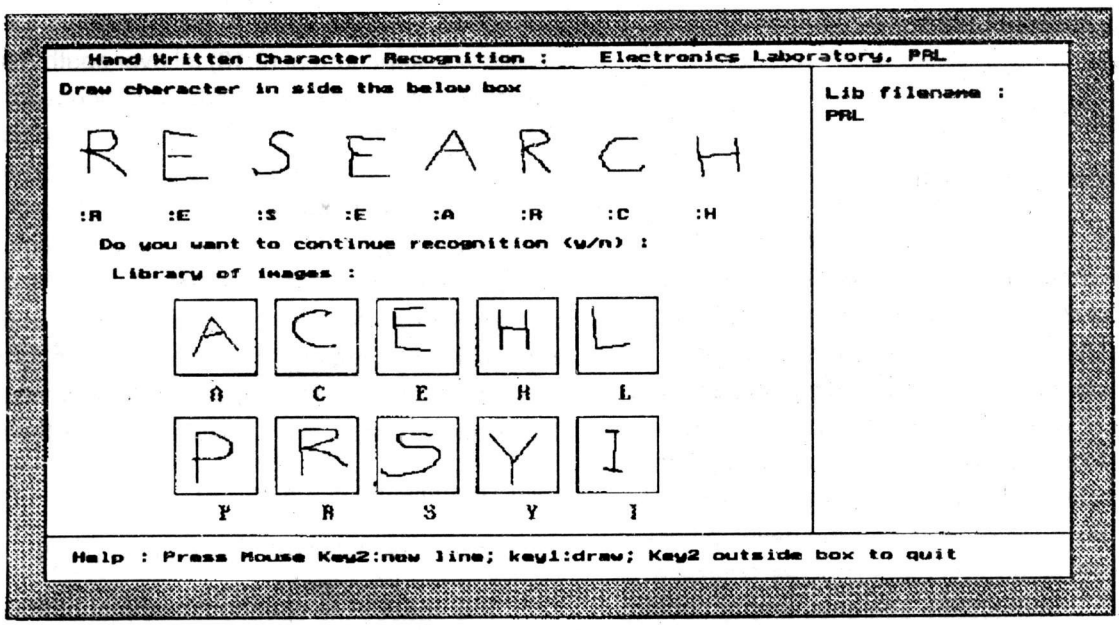

Fig. 2.6a : An example of hand written character recognition package developed at Electronics Laboratory.

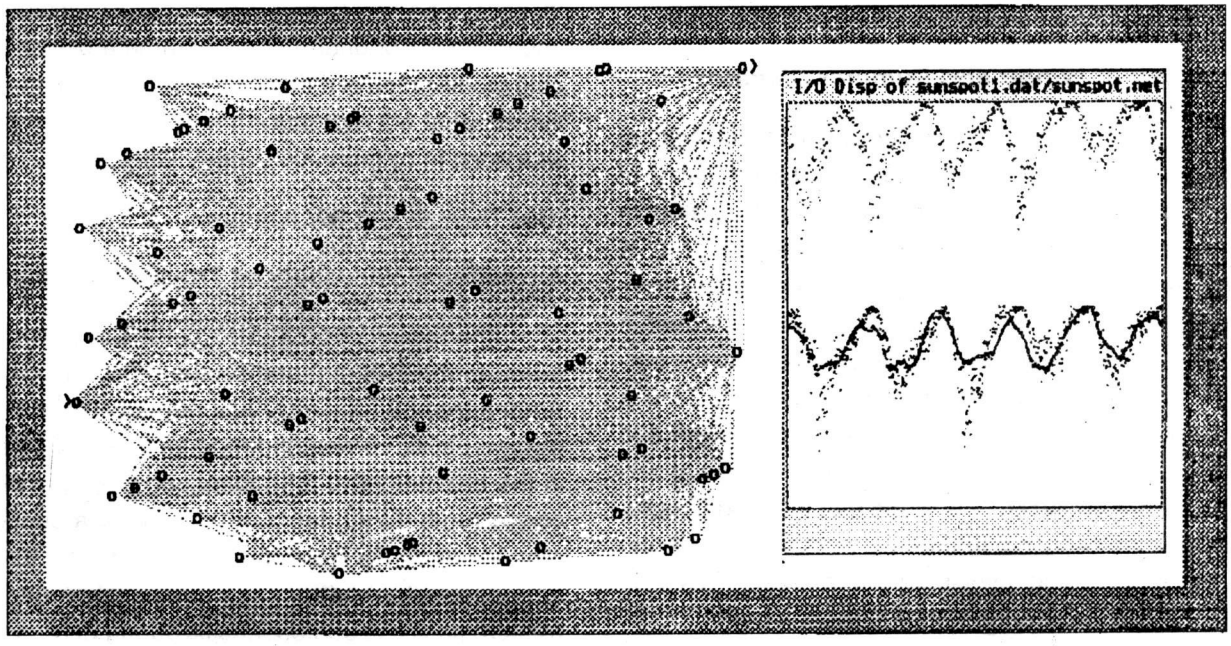

Fig. 2.6b : The figure at left is randomly connected network with delay neurons to predict sunspot activity. The figure on right shows the input sunspot cycles (top trace) with predicted and desired output (bottom traces) for 55 years data.

further used to drive a character recognition in it for any Indian language.

(H.S.Majumdar)

Neural Networks for Control

Conventional sensor based robot control system can overcome many difficulties faced in generating the dynamics of the robot arm. Instead adaptive neural controllers can be used for the internal representation of the dynamics and system can change with changing requirement of the robot arms. A pioneer robot platform has been procured to build test and validate the adaptive algorithms to real life application. Also a fuzzy comparator development system has been procured for the development of fuzzy logic based pattern comparator for real time date for robotics control and database searches and to develop dedicated hardware for this kind of application.

(H.S.Majumdar)

METEOROLOGY AND CLIMATE STUDIES

Simulation of Winter and Summer Climates

The Atmospheric General Circulation Model (AGCM) which was developed last year, was used for simulation of winter and summer climates. The GCM was integrated for five years starting as an isothermal atmosphere (240° K at all levels), zero winds initial conditions and forcing from incoming solar radiation. The boundary conditions used in the model include seasonally varying sea surface temperature (SST), sea-ice and albedo from climatology. Clouds are calculated interactively from the model prognostic variables. The last four years seasonal averages of various fields are analyzed. It is found that the model reproduces well the seasonal features of atmospheric circulation, its variability and hemispheric differences. This work was done in collaboration with V.Satyan.

(Biju Thomas and S.V.Kasture)

Sensitivity of South Asian Summer Monsoon to Surface Albedo

To understand the role of bottom boundary condition (albedo) to Summer Monsoon, two experiments were carried out using the GCM. In the control run the surface albedo was kept normal (0.13) all over south Asia and in the other experiment the albedo was increased to 0.20. We integrated the model for three months in each case and found that an increase of surface albedo results in reducing land-sea contrast, weakening of south-westerlies at lower levels and reducing sensible heating, evaporation and precipitation. So the model results show that a major deforestation in south Asia will lead to decrease in rainfall in that region. The initial condition for both the runs are taken from the five year run mentioned above. This work was done in collaboration with V.Satyan.

(Biju Thomas and S.V.Kasture)

Tropical Intraseasonal Oscillation (TIO)

The space-time spectrum analysis of May to September model outputs was carried out to see how the GCM represents the TIO. One main discrepancy of present day GCMs is that they produce TIO of shorter periods (< 30 days) than it is observed (50 days). It was found that by improving the boundary layer parameterization and suitable modification of moisture convergence in the convective scheme will reproduce the observed TIO. This work was done in collaboration with V.Satyan.

(Biju Thomas and S.V.Kasture)

Interannual Variability of Tropical Circulation

Interannual Variability of Tropical Circulation is mainly associated with El Nino and Southern Oscillations (ENSO). An idealized SST anomaly was introduced over equatorial eastern pacific corresponding to an El Nino SST anomaly in the climatological SST data used in the model. The control run is the model run with same initial condition and climatological SST distribution. It is found that model reproduces the shift of main precipitation centre from western pacific to eastern pacific during El Nino. Also, as it is observed, model reproduces weak monsoon circulations in terms of weak low level south westerlies and weak upper level easterlies and reduced precipitation in the anomaly run. This work was done in collaboration with V.Satyan.

(Biju Thomas and S.V.Kasture)

This is a new division of PRL. The activities of this division have been primarily theoretical though the process of setting up of various laboratories has been started and the equipment has been ordered. Theoretical work has covered a wide spectrum of topics from the fields of quantum optics, nonlinear optics and laser physics such as- quantum optics of nonlinear systems; optical manipulation of atoms; control of spontaneous emission, laser cooling; fractional Fourier Transforms; radiation from correlated systems and generation of nonclassical light. Several collaborative projects with some of the major experimental groups have been initiated. Some of the research activities are summarized below.

Observation of Two-Photon Decay of Rydberg Atoms in a Driven Cavity

Enhanced two-photon decay has been observed for the first time in an electric dipole transition between two Rydberg levels coupled to a single mode of a strongly driven microwave cavity. This was achieved by dynamically suppressing the otherwise dominant single-photon decay. The experiment is compared with a dressed-state model which treats the external driving field exactly. Cavity-induced emission and absorption rates are calculated to fourth order in the interaction to include two-photon processes, and are found to fit the experimental data well. This work was done in collaboration with W. Lange and H. Walther of Max-Planck Institut für Quantenoptik, Germany.

(G.S. Agarwal)

Unitary Inequivalent Classes of SU(1,1) Coherent States

The coherent states of a Hamiltonian linear in SU(1,1) operators are constructed by defining them, in analogy with the harmonic-oscillator coherent states, as the *minimum-uncertainty* states with *equal variance* in two observables. The proposed approach is thus based on a physical characteristic of the harmonic-oscillator coherent states which is in contrast with the existing ones which rely on the generalization of the mathematical methods used for constructing the harmonic-oscillator coherent states. The set of states obtained by following the proposed method contains not only the known SU(1,1) coherent states but also a new class of states hitherto unknown. This work was done in collaboration with R. R. Puri of Bhabha Atomic Research Centre, Bombay.

(G.S.Agarwal)

Controlling Light by Light

We demonstrate the application of electromagnetic-field-induced transparency and quantum interference effects in the cooperative phenomenon such as optical bistability. The control field used in tandem with the usual electromagnetic field of the two-level scheme results in a considerable lowering of the threshold intensity. We discuss the transient response of the system in the mean-field limit and describe the regression to the steady state when perturbed away from it; the regression exponent is itself dependent on the control field. We also demonstrate the possibility of control-field-induced multistability in two-level systems. This work was done in collaboration with W. Harshawardhan of University of Hyderabad.

(G. S. Agarwal)

Sub-Doppler Spectroscopy

Experiments in nonlinear optics and spectroscopy are often performed in atomic vapors, where the linewidths of the transitions of interest are dominated by Doppler broadening. We propose a scheme for obtaining sub-Doppler resolution for one transition of an inhomogeneously broadened, three-level atomic system, by using an intense control field at the other transition. Analytical and numerical calculations are presented to delineate the mechanism responsible for this sub-Doppler resolution, and quantify the extent to which Doppler broadening can be reduced. Results for a variety of optical transitions are given. This work was done in collaboration with Gautam Vemuri and B. D. Nageswara Rao of Indiana University-Purdue University at Indianapolis, U.S.A.

(G. S. Agarwal)

Optical Parametric Interactions in Quantum Regime

We discuss the dynamics of parametric systems and in particular we treat the down conversion process.

We show that the dynamical evolution of mean occupation of various modes exhibit *collapse and revival phenomena* if the pump field is in a coherent state. This is reminescent of Jaynes-Cummings model consisting of a two level system interacting with a single mode radiation field. The periodic behavior of the atom interacting with a classical field, collapses and revives due to quantized nature of the energy levels. The semiclassical dynamics of parametric system also shows periodic behavior which is collapsed and revived if all the modes are quantized. In addition we demonstrate the existence of *fractional revivals* even if the parametric system is interacting with a pump in a *coherent* state. This is in *contrast* to Jaynes-Cummings model. We further show that fractional revivals become much more pronounced if the coherent pump is replaced by a pump with sub-Poissonian statistics. This new behavior of parametric systems is connected to *multilevel nature of the sets* of states for the *trilinear* Hamiltonian. Each revival is a superposition of macroscopic quantum states and thus such states are useful in studying fundamental questions like interference between different parts of a wavepacket. Our results show how the nonlinear systems provide us with alternate candidates for exploring new quantum phenomena like fractional revivals. This work was done in collaboration with Iyyanki V. Jyotsna of University of Hyderabad, Hyderabad.

(G. S. Agarwal)

Quantum Dynamics of Classical Dressed Mode in Nonliner Optical Interactions

When the mean number of photons in the sub-harmonic and fundamental modes are much greater than unity, then the Heisenberg equations of motion for the up/down conversion process can be solved classically by replacing the annihilation and creation operators by c-numbers. We consider the special case for which, classically, there is no energy exchange between the two modes and the mean number of photons in each mode remains constant in time. In the quantum mechanical version, we have found fluctuations about the classical solution leading to fractional revivals.

(G. S. Agarwal and J. Banerji)

Ramsey Spectroscopy with Nonclassical Light

The Ramsey spectroscopy is a very useful technique yielding high resolution, and has been extensively used in many different contexts. The signal in such a setup has been calculated and interpreted in terms of the interference between two quantum-mechanical pathways. In view of the current interest in doing spectroscopy with squeezed light and other types of nonclassical radiation it is desirable to examine the use of nonclassical light in Ramsey spectroscopy. In particular it would be important to know if the signal-to noise ratio can be improved using nonclassical sources. The noise arises from the statistics of the atomic beam, statistics of the field used to excite the atoms, and intrinsic quantum noise. In this paper we calculate the signal-to-noise ratio for the standard two-field Ramsey method. We also discuss how the use of sub-Possionian light can lead to an improvement in the signal-to-noise ratio. This work was done in collaboration with Marlan O. Scully of Texas A & M University, USA.

(G. S. Agarwal)

Nonlinear Magneto-Optical Effect

J. P. Connerade has done extensive experiments on magneto-optical effects in atomic vapors. He has also studied systematically the nonlinear regime of magneto-optical effect by increasing the intensity of the linearly polarized laser beam propagating through the medium. He also reports the changes as the density of the atomic medium is increased so that one is dealing with optically thick vapor. Theoretical modelling of these experiments has been undertaken and the initial results support many of the experimental observations. This work was done in collaboration with P. Ananthalakshmi of University of Hyderabad and J. P. Connerade of Imperial College London.

(G. S. Agarwal)

Lasing Under Bichromatic Pumping

A major development in the area of lasers is the possibility of producing lasing under conditions of *no* population inversion. This idea was against the usual thinking. However one understands it in terms of the very

important atomic coherences which are practical from coherent pumping. A natural question is how to enhance gain under such conditions. An idea is to make atomic coherences more dramatic by using bichromatic pumps for coherent pumping. A model V-system is under study and the preliminary results have shown the enhancement of gain as a result of bichromatic pumping . This work was done in collaboration with T. W. Mossberg of University of Oregon, USA.

(S. Arun Kumar and G. S. Agarwal)

The results in brief, of the various research activities in the fields of upper atmosphere, middle atmosphere, planetary and cometary atmospheres and laboratory astrophysics are described in the following sections:

UPPER ATMOSPHERE

Optical Measurements of Daytime Aurora

New results have been obtained from the daytime auroral measurements by including north pointing scans in the multiwavelength daytime auroral photometer from the Indian Antarctic station, Maitri, during the XIV Indian expedition. The latitude region of particle precipitation was found to lie north of Maitri centered ~ 58°S magnetic latitude. The proton and electron precipitation regions were dispersed in space and found to maximize around local noon time. Significant shift in the latitude of maximum activity has been detected with magnetic activity. The foot of the magnetic field lines passing through the region of maximum activity eventually gets mapped to the plasma pause region which refers to the boundary between the 'corotating' geomagnetic field lines and the 'frozen' ones. Therefore, the particle precipitation pattern is inferred to be directly related to the changes occurring around the plasma pause, which itself is in dynamic equilibrium due to the varying solar wind ram pressure. The conclusion is in conformity with those from the satellite borne measurements.

(R. Sridharan, D. Pallam Raju, N. K. Modi and R. Narayanan)

Behaviour of the Low Latitude Thermosphere during Geomagnetic Storms and its Representation by improved MSIS-model:

The thermospheric temperatures from low and equatorial latitudes are known to show significant deviations from those predicted by the atmospheric models during geomagnetic storms. Many times they show large oscillatory features of few hours periodicity, more so during geomagnetic storms and the models lack the finesse to predict them. Keeping the basic formulation of the model the same, improvements were worked out. A unique relation was established between the difference in the observed and model predicted temperatures (ΔT) and the D_{st} magnetic index. Using this relation a correction term was worked out to the latest MSIS-90 (Mass Spectrometer and Incoherent Scatter - 90) model and all the observed variations in the neutral temperature from a low latitude station Mt. Abu, were successfully explained during two geomagnetic storms. One of the intriguing aspects of temperatures going below the model predicted values is also explained to be directly related to the rate of energy exchange from the earth's ring current ie. dD_{st}/dt.

(Tarunkumar Pant and R. Sridharan)

High Resolution Maps of OI 630.0 nm Dayglow

The first high spectral and spatial resolution 2-D maps of OI 630.0 nm dayglow emission features have successfully been obtained from equatorial region by operating the dayglow photometer in an all sky scanning mode covering ± 4° in latitude and longitude scale with respect to zenith coordinates. Distinct movements of airglow emission regions presumably associated with the special geophysical processes like the Equatorial Ionization Anomaly (EIA) have been obtained. Hitherto unknown, intricate, wave like features are identified to be associated with the crest of the EIA. The surface plots **(Fig. 4.1)** clearly depict the same and indicate the crest regions to be a source of these waves.

(D. Pallam Raju, R. Sridharan and N. K. Modi)

Imprint of Equatorial Electrodynamics On OI 630.0 nm Dayglow

Results from the systematic measurements of OI 630.0 nm dayglow from the dip equator (Trivandrum) have revealed clear evidence for the significant influences of the electrodynamical processes on the temporal variability of the OI 630.0 nm dayglow. The primary zonal electric field which is mainly responsible for the electrodynamical processes like the equatorial electrojet and the equatorial ionization anomaly, is inferred from the intensity of the electrojet current at any particular instant and is estimated from the variation of the horizontal component of the geomagnetic field. Remarkable

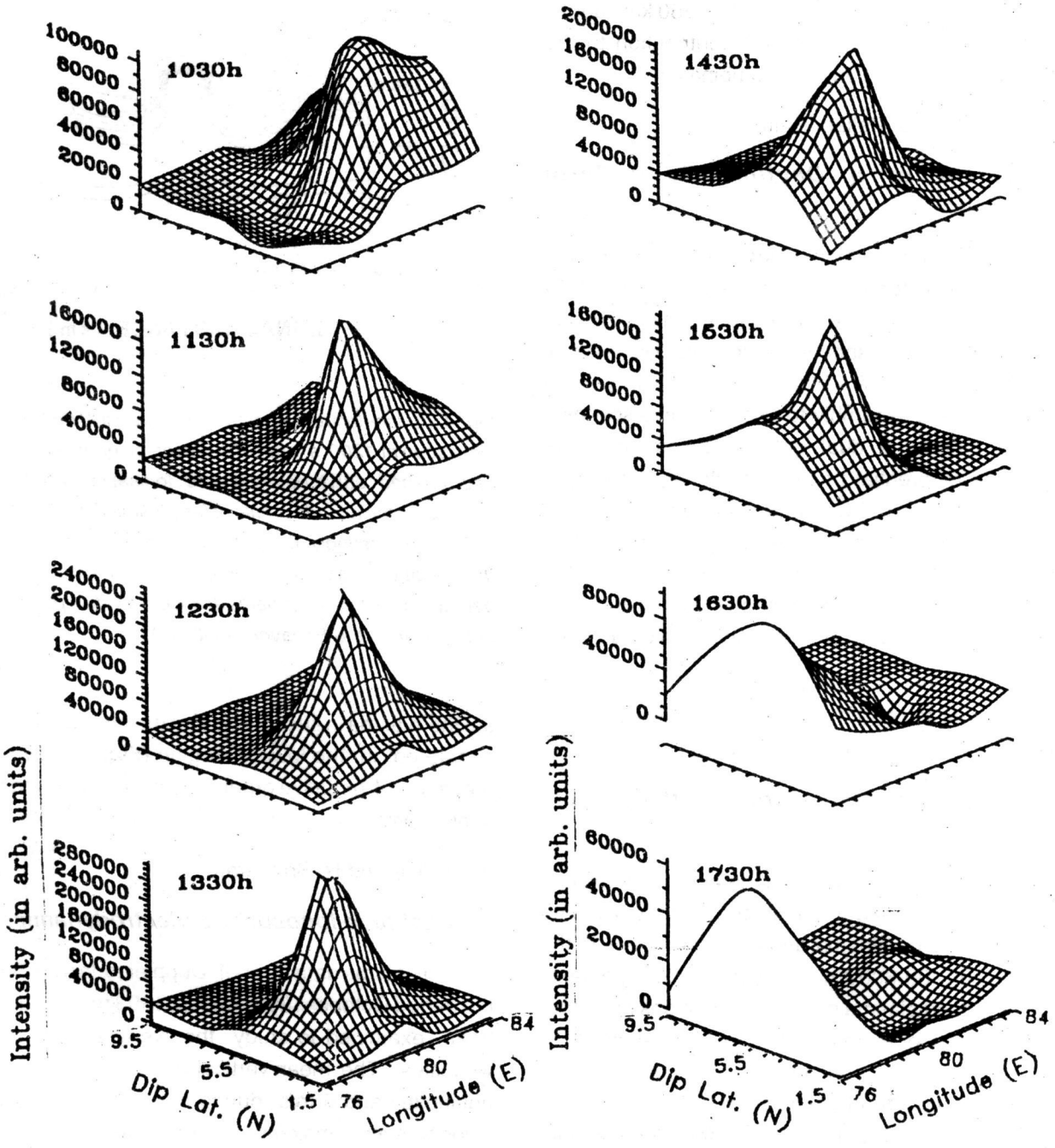

Fig. 4.1 : High resolution surface plots of OI 630.0nm day glow depicting the wave like features associated with the evolution of Equatorial Ionization Anomaly (EIA)

similarities have been obtained between the ground magnetic data and the temporal variations exhibited by the dayglow, but with varying time delays. The stronger the electrojet on a particular day the smaller had been the time difference. This has been attributed to the vertical uplift of the plasma from lower region to ~ 250 km, due to the **E x B** drift and its consequent contribution to the dayglow through dissociative recombination.

(R. Sridharan and D. Pallam Raju)

Development of a Daytime Fabry-Perot Spectrometer

A unique, single etalon, high resolution Fabry-Perot spectrometer for line profile determination of OI 630.0 nm dayglow from the thermosphere has successfully been built. The spectrometer employs several innovative elements. A high resolution Fabry-Perot etalon, spiral mask assembly to enable spatial scanning of the FP fringes, a dual gate scanning technique, synchronized differential photon counters along with completely automated PC controlled operation had enabled the success of the above spectrometer. During the course of this technological breakthrough, a new innovative method of *on line* electronic gate scanning of the fringes to obtain the emission line profile had been demonstrated.

(R. Sridharan, N. K. Modi, T. K. Pant, D. Pallam Raju, Alok K. Tauri, D. Chakrabarti and V. R. Mutagi)

On the Generation of irregularities In the Lower F-region

Rocket measurements from the equatorial regions during equatorial spread-F events consistently revealed the presence of the plasma density irregularities in the lower F-region (200-300 km) where the vertical gradients in the background plasma density distributions are either positive but small or even negative. An investigation is carried out using a nonlinear numerical simulation model and the results obtained from 'Ionization Hole' rocket campaign, in order to explain the development of irregularities in the negative gradient region. It revealed that the penetration of the fringe fields associated with a plasma bubble at the base of F layer (~ 350 km) redistribute the plasma in such a way that the irregularities can be generated in the lower F-region **(Fig. 4.2)** even in the presence of negative gradient in the background plasma density profile.

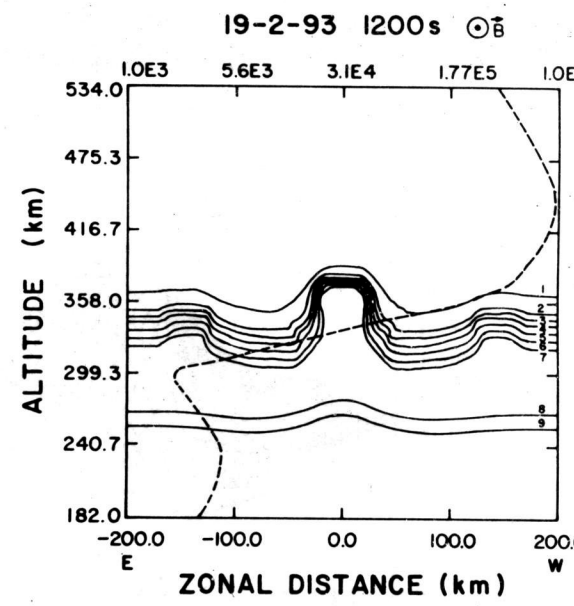

Fig. 4.2 : Isoelectron density contours in the region of simulation at 1200 s after the onset of equatorial spread-F. The dashed curve based on the Ionisation Hole Campaign represents the altitude profile of the plasma density at the onset of ESF. Interestingly, the instability process is found to grow in the negative gradient region (250 - 280 km) owing to the penetration of the fringe fields associated with a plasma bubble at the base of the F - layer (~350 km).

(R. Sekar and R. Sridharan)

Low Latitude Ionospheric Electrodynamics

Nighttime data from HF Doppler radar at 5.5 MHz for the period October 1992- August 1993 from Nagpur have been examined to study the vertical F-region drift velocities. The mean vertical velocity is 8 m/s during the equinoxes and 6 m/s during solstices, the post sunset velocity is also maximum during the equinoxes. Comparison with the results reported for the low latitude stations Trivandrum, Waltair and at Varanasi shows a fair agreement in the pattern, with stronger electrodynamic

effects at Waltair and Trivandrum. This work was done in collaboration with Prof. G.N. Navneeth of Nagpur University.

(H. Chandra)

Solar Eclipse Effects On the Ionosphere

Ionospheric effects of the total solar eclipse event of 24 October 1995 over Ahmedabad with maximum obscuration of 83% at 0800 hr (70° EMT) were studied based on ionograms obtained every minute. True height analysis of the quarter hourly ionograms was done to study the effects at different real heights. Comparison with the results on the control day, 23 October 1995 (**Fig. 4.3**) shows decreases of maximum electron densities of about 57%, 69% and 28% in the E, F_1 and F_2 regions respectively. Maximum eclipse associated decrease is seen around 200 km. There is some indication of wave activity especially at altitude near the F_2 peak soon after the onset of the eclipse.

(G.D. Vyas, H. Chandra, S. Sharma and Bharati Bhatt)

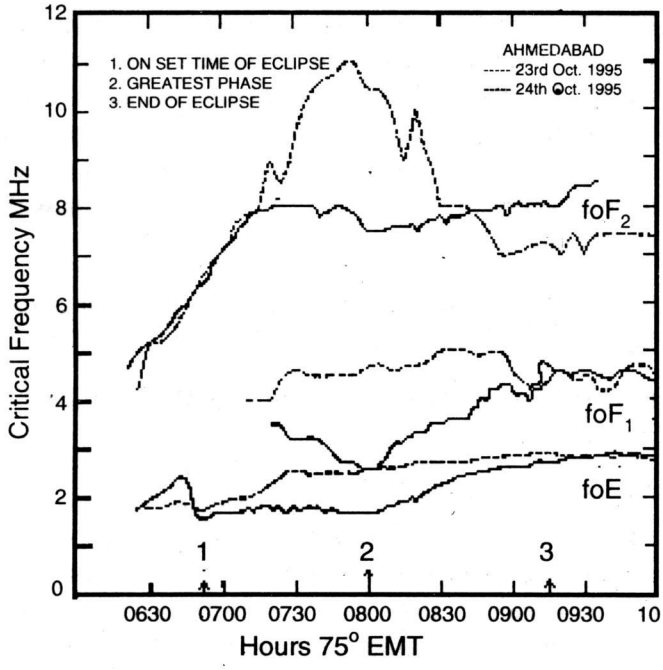

Fig. 4.3 : Time variations of the critical frequencies of E, F_1, F_2 layers over Ahmedabad during the total solar eclipse (24 October 1995) and control day (23 October 1995).

Geomagnetic Field Variations at Low Latitudes

Geomagnetic horizontal H field variations at equatorial stations in general show a steady decrease after sunset throughout the night at stations in the Indian and African sectors but a steady increase after midnight is seen in the American sector during equinoxes and June solstices. There is a remarkable similiarity in the nocturnal variations of the H field at Huancayo and the ionospheric electric field determined from the backscatter radar measurements at Jicamarca. The magnetic field variations during the night time over Huancayo appear to be due to the ionospheric electric field changes.

Geomagnetic field data at a number of stations in Asia showed the disintegration of the vortex structure during the winter months in the northern hemisphere. This is associated with the weakening of the eastward (Y) field due to the hemispherical inequality in the ionospheric wind system.

The geomagnetic field components H, Y and declination (D) at the equatorial electrojet station, Kodaikanal have been studied for more than 300 geomagnetic storms. During the main phase of the storms the fluctuations in H and D vary synchronously. Occasionaly there are large decreases in the H field during day time with no corresponding decrease in H at Alibag or in the D_{st} index and are associated with the disappearance of the equatorial type of E indicating a temporary reversal of the electric field over the magnetic equator. This work was done in collaboration with Prof. R.G. Rastogi and Dr. M.E. James of Gujarat University.

(H. Chandra)

Longitudinal inequalities in the Equatorial Electrojet

There are two well marked longitudinal inequalities in the equatorial electrojet parameters in the Indian and American regions in terms of the altitude of the electrojet peak and its magnitude. In order to explain these observations, calculations of Pedersen, Hall and Cowling conductivities were made using the same plasma and neutral parameters but the actual observed ground mag-

netic field values for both the regions. It has been shown by this study that it is the parameter R_i (the ratio of the ion-neutral collision frequency to the ion-gyrofrequency) which seems partly responsible for the altitude difference of peak current densities in both the regions. It was shown that the second inequality can be explained if the ground ΔH variations of both the regions are normalized to the same epoch of the solar activity. It was also found that the peak current density and the peak Cowling conductivity are higher by 29% and 73%, respectively, in the American region as compared to that in the Indian region. This work was done in collaboration with Prof. R.G. Rastogi of Gujarat University.

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

Features of E region irregularities at Thumba and SHAR

Rocket borne measurements carried out over Thumba (dip 0.5°) around noon time covering different seasons and solar activities were compared with those from SHAR (dip 13°). Sharp layers of ionization were restricted only to counter electrojet periods over Thumba while it was a regular feature over SHAR, while the nature of 1 to 300 m scale size irregularities were found to be the same. Type I irregularities were totally absent over SHAR while they are present in the 105-107 km region over Thumba. During nighttime, whenever type-I irregularities were detected from Thumba they were restricted to only around 106-107 km where the electrojet current density is known to maximise during noon time. This is an indication for the presence of significant electric fields even during nighttime on certain occasions.

(S.P. Gupta)

MIDDLE ATMOSPHERE

Ozone Measurements over the Indian Ocean

Insitu surface ozone measurements were carried out during January 5 to February 3, 1996 on board the

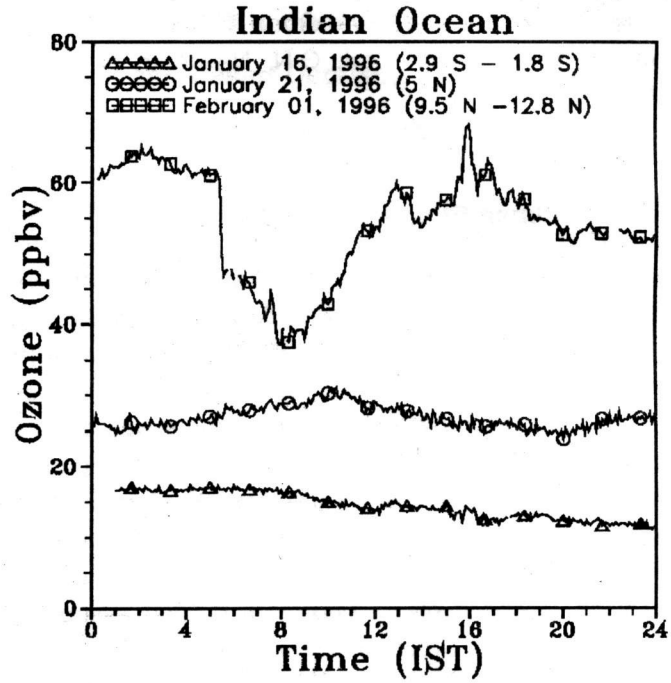

Fig. 4.4 : Diurnal variations of surface ozone at different latitudes over Indian ocean.

ORV Sagar Kanya covering the latitude 16° N-5° S and longitude 71°-60° E as a precampaign for the INDOEX (Indian ocean experiment). During this cruise, air samples were also collected for the analysis of various trace gases. Preliminary results reveal no diurnal variation from about 5° N to 5° S indicating a cleaner environment during this period. However, in other regions it shows diurnal variation of typical to the urban/remote environments (**Fig 4.4**).

(K.S. Modh, M.Naja, T.K.Sunil, S. Desai, S. Venkataramani, Shyam Lal and B.H. Subbaraya)

Distribution of Nitrous Oxide and Methane in the Arabian Sea

Measurements of the important biogenic gases N_2O and CH_4 were made both in the water column and over the marine air of the Arabian sea during April-May 1994 and February-March, 1995, as a part of the JGOFS (India) programme. The average abundances of N_2O and CH_4 in the marine air are 313 ± 7 ppbv and 1.66 ± 0.05 ppmv respectively. The vertical profiles of N_2O in water column show double peak structure. The entire water column is

super-saturated with respect to N_2O and in the primary peak region it is saturated by as much as 600-800%, suggesting the Arabian sea to be a major reservoir of N_2O. The intensity of the peak increases towards higher latitude which is coincident with the strength of denitrification. The N_2O sea-air flux was significant only during 1995 (0.6 pg $cm^{-2}s^{-1}$).

Methane measured down to 400 m depth shows a peak concentration as high as 6-8 nmol in the 100-200 m depth region. Super saturation (up to 200-400% at the peak) is found for CH_4 in most of the latitudes. Average methane sea-air flux values are about 0.05-0.08 pg $cm^{-2}s^{-1}$, with lower values during 1994.

(Prabir K. Patra, S. Venkataramani, T.K. Sunil and Shyam Lal)

Vertical Profile of Sulphur Hexafluoride (SF_6)

Sulphur hexafluoride (SF_6) emitted from earth's surface by anthropogenical activities is being used as an atmospheric tracer due to its long life. The vertical distribution of SF_6 was measured by a balloon-borne cryogenic air sampler from Hyderabad (17.5° N, 78.6° E) on April 16, 1994 in the altitude region of about 8-37 km. The profile shows a steep decrease between 17 - 27 km. This indicates very little loss of SF_6 due to photo-chemistry in the stratosphere which is in conformity with the NASA/GSFC model predictions.

(Prabir K. Patra, S. Venkataramani, Shyam Lal and B. H. Subbaraya)

Estimation of Total Peroxy Radicals Over Low Latitudes

O_3, NO_2 and NO are the three major participants in the tropospheric photochemistry and are interrelated through a primary photochemical cycle which makes a photostationary steady state (PSS). This PSS condition can be used for determining ozone concentrations and its dependence on NO_x, in different environments. But in remote/clean environments this PSS needs some modification because of the role of peroxy radicals [RHO_2] as oxidants. A calculation has been made to study the distribution of total peroxy radicals and their effect in different environments by making use of O_3 and NO_x data and photodissociation coefficient for NO_2. The calculations revealed significant diurnal and seasonal variation with higher production during winter. In the regions of lower NO_x concentrations, high values of total peroxy radicals have been found. Calculated concentrations of total peroxy radicals for Ahmedabad with higher [NO_x] are in the range of 25-55 ppbv whereas for Gadanki, a relatively cleaner site with lower [NO_x] it is 100-120 ppbv.

(M. Naja, K.S. Modh, S. Venkataramani, Shyam Lal and B.H. Subbaraya)

Aerosol Optical Depth and Size Distribution Over Ocean Surfaces

Direct solar radiation intensities at five spectral bands, each centered around 399 nm, 497 nm, 667 nm, 848 nm and 1051 nm and with a bandwidth of around 10nm were measured as a part of the INDOEX experiment and the total optical depths were obtained after accounting for contributions from air molecule scattering and gaseous absorptions. The steep rise in aerosol optical depth seen at the lower wavelength is caused due to the presence of large number of smaller particles, of size less than 0.5μm and could be of sulfate and nitrate particles of land origin. Using a Quartz Crystal Microbalance cascade impactor system, aerosol particles were collected in ten different stages with particle diameter ranging from 0.05μm to 25μm over the Arabian sea and Indian ocean and were analyzed for their mass concentration and size distribution. Two prominent modes were found in the size distribution of particles sampled over the Arabian sea, one at 0.1 μm and the other at the 25μm region. The observed increase in the number of small particles near the coastal region supports the sun-photometer observation of the increased aerosol optical depth as well as the steep gradient observed in the spectral characteristics of the aerosol extinction.

(A. Jayaraman and S. Ramachandran)

Nd:YAG Rayleigh Lidar at Mount Abu

The Nd:YAG backscatter lidar operational at PRL

since 1992 has been shifted to the newly constructed Optical Aeronomy Observatory at Mount Abu in March 1996. Apart from aerosols, the vertical structure of the neutral number density distribution, temperature profile and the gravity waves could now be studied upto mesospheric heights. Above ~ 30 km the amount of aerosols in the atmosphere is negligbly small and hence the measured backscattered radiation intensity could completly be attributed to Rayleigh scattering by air molecules. A new cassegrain telescope with 90 cm diameter primary mirror is installed to collect the backscttered light signals up to about 80 km. The backscattered intensity measured in terms of number of photons is plotted with altitude after range corrections (**Fig. 4.5**) alongwith computed signal strength for a model air density profile. The large increase in signal strength seen below about 15 km is due to the presence of aerosol particles, produced as a consequence of a dust storm two days prior to this measurement.

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

Vertical Electric Field in the Low Latitude Stratosphere

Vertical electric field was measured by balloon borne probes over Hyderabad on 11 April 1988, 17 October 1989 and 5 January 1994. The measurements were carried out from about 15 km onward till float altitude. The electric field values at the altitudes 17 km, 24 km and 31 km are 7, 2.6 and 1 V/m respectively. This shows that the scale height is about 7 km. Though these measurements are in agreement with measurements made at San Marco equatorial station over Kenya, they are higher by a factor of two compared to a mid latitude station like Wallops Island probably due to the latitudinal dependence of conductivity.

(S.P. Gupta)

Volcanic Aerosol Loading of Low Latitude Stratosphere

Zenith measurements of scattered solar radiation (800 nm) intensity during twilight period when the earth's shadow gradually sweeps upward thus providing an

Nd:YAG Rayleigh lidar made operational at Mount Abu

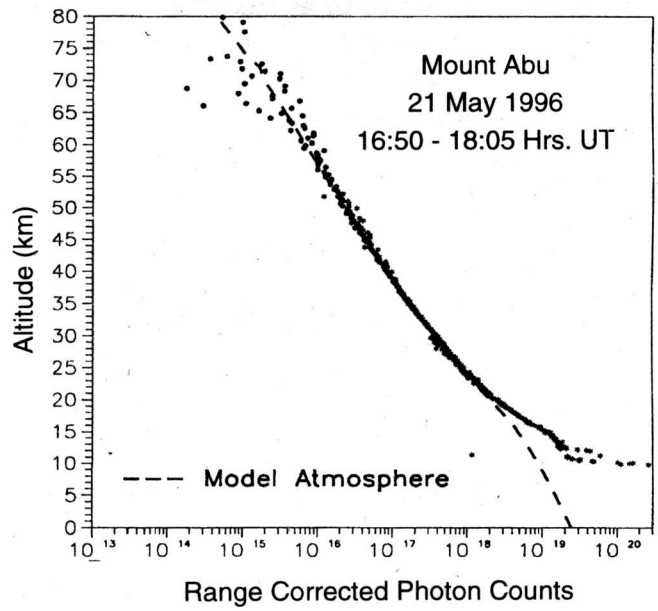

Fig. 4.5 Lidar measurements of back scattered intensity (altitude resolution 96m below 40km and 384m above) along with model air density profile.

altitude scan, have been carried out after the Pinatubo volcanic eruption providing clues to the aerosol loading of the stratosphere. The lower height of the aerosol layer (HL) lies between 18 and 25 km with a mean value around 21.5 ± 3.5 km for the period of November to February 1992 in conformity with SAGE II satellite and balloon-borne measurements during that period. The thickness of the aerosol layer was about 12 ± 0.48 km during the end of November and beginning of December 1991, reached a minimum (~ 6.5 ± 0.26 km) in the month of January 1992 and then increased to about 12 km in the last week of February 1992. In comparison ΔH was found to lie between 8 and 9.4 km in the month of June 1982 after ElChichon eruption.

(M. Lal and D. K. Chakrabarty)

Behaviour of Ozone Over Indian Region after Pinatubo Eruption

The reported decrease of ozone after Pinatubo eruption was attributed to be due to the heterogeneous reactions. The behaviour of total ozone after Pinatubo

eruption over the Indian region studied by us using the Dobson data from New Delhi (28°N) to Kodaikanal (10°N) revealed that , there is no spectacular decrease of O_3 immediately after volcanic eruption i.e. during the second half of 1991 as compared to those at 1970 - 1990. Also, values obtained during 1991, 1992 and 1993 are well within those at 1970 - 1990 except in Delhi. Ozonesonde observations at Pune (18°N) and balloon measurements of aerosol profile at Hyderabad (17.5°N) show that the altitude of ozone peak is about 5 km higher than the altitude of the aerosol peak. Based on these results and also the supporting evidence that there is no corresponding decrease in the stratospheric NO_2 as the heterogenous reactions, if present, would have carried a decrease in NO_2 also, it is concluded that the these reactions may not play a significant role in the ozone chemistry in the low latitude region. This work was done in collaboration with Mr. S. K. Peshin of India Meteorological Department, New Delhi.

(D. K. Chakrabarty)

Effect of Solar Eclipse on Ozone Column Density Over Ahmedabad

Measurement of vertical column of ozone over Ahmedabad (23°N) during the solar eclipse (24 October 1995) event was made by a Dobson spectrophotometer (**Fig. 4.6**). The maximum obscuration at this place was about 83% at 0835 IST. There was no significant change in the ozone columnar density on 23 October and 25 October. But during the eclipse, prior to maximum obscuration, there was a sharp fall in the ozone value followed by an increase by about 35 DU from the normal level. After about 0850 IST, the ozone value became almost normal though a wavelike fluctuation possibly due to eclipse induced gravity waves was seen similar to other eclipse events elsewhere. In view of long life time of ~ 1 month ozone in the stratosphere, such a fluctuation in total ozone calls for a detailed investigation.

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

Theoretical Model of Stratospheric Ions

A detailed ion chemical scheme overcoming the limitations of the previous one has been developed in which 18 positive ions and 23 negative ions including clustered ions have been considered to identify the actual

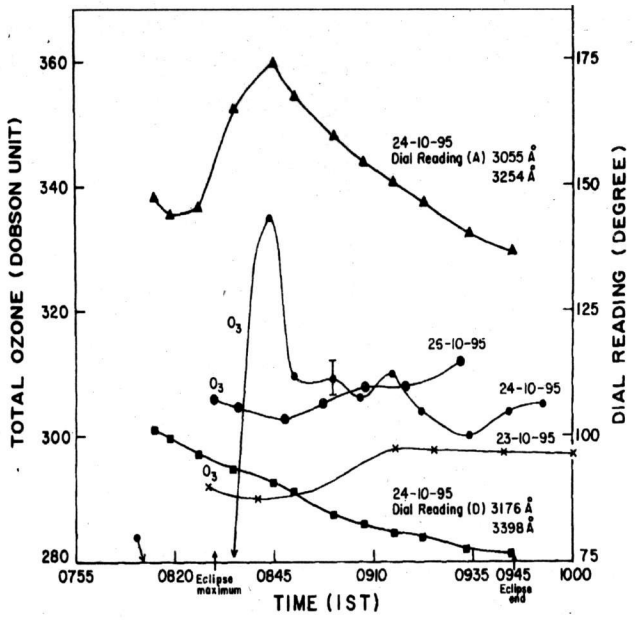

Fig. 4.6 : Variation of ozone columnar density on 23rd, 24th (eclipse day) and 25th of October 1995.

processes and the ion compsoition of the stratosphere. Continuity equations of all the ions are solved simultaneously for the steady state condition. Preliminary results show that at mid latitude predominant ions at 20 km and 45 km are $H^+ .(CH_3 CN)_3 .H_2O$, $NO_3^- .(HNO_3)_2$ and $H^+.(H_2O)_3$, $H^+.(H_2O)_4$, CO^-_3 , HCO^-_3 respectively.

(D. K. Chakrabarty)

LABORATORY ASTROPHYSICS

Total Electron Scattering Crosss Sections of Carbon Dioxide

Total electron scattering cross sections for carbon dioxide have been measured at low electron energies using a photoelectron source. The measurements have been carried out at a large number of electron energies varying from 0.91 to 9.14 eV with an accuracy of better than ±3% at a fairly high electron energy resolution of about 40 to 45 meV and by employing better discrimination against small angle scattering. The typical energy dependence in the electron scattering cross section (**Fig. 4.7**) shows the presence of a virtual state at low energies (less that 1 eV) followed by the occurrence of

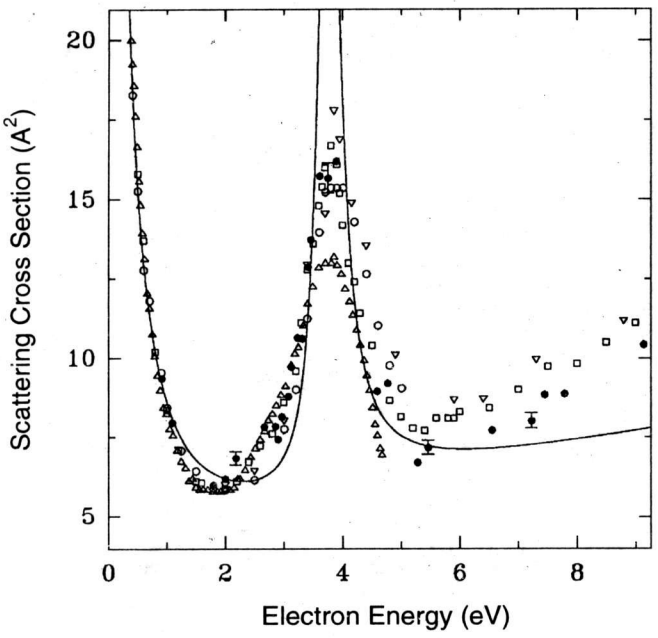

Fig. 4.7 : Total electron scattering cross section for carbon dioxide as a function of incident energy from 0 to 9.14 eV obtained by various researchers. The symbols denote: o, Buckman et al (1987); ∇, Hoffman et al (1982); —, Morrison et al (1977); □ Szymtkowski et al (1987); Δ, Ferch et al (1981); ● present work.

the temporary negative ion state, also called the shape resonance, at about 3.8 eV. But, in the present work, it has been shown that another shape resonance at about 2.49 eV occurs. This is suggested to a be due to the formation of another temporary negative ion state created because of e-CO_2 (010) interaction.

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

Temperature Dependence of Photoabsorption Cross Section of SO_2

Photoabsorption cross sections of sulphur dioxide have been measured in the spectral region 280-320 nm for temperatures ranging from 220 to 300 K at an interval of 20 K. These measurements have been carried out with an accuracy of about ±4% at an instrumental resolution of 0.1nm. In the above thermal transpiration effects in pressure and absorption effects in incident intensity has been taken into account. Magnitudes of these corrections depend mainly on the temperature of the target gas used. The absorption system being studied in the present experiment consists of discrete bands superimposed on an apparent continuum. We have studied the temperature dependence of photoabsorption cross sections of the whole band system which includes the contributions from both. The cross section values at the peaks of the discrete bands increase with the decrease in temperature, while the cross section values decrease with the decrease in temperature in case of continuous absorption. The photoabsorption cross sections measured in the present experiment can be explained in terms of the added effect of the two types of temperature dependence at different incident photon wavelengths.

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

Fluorescence Studies and Radiative Life Time Measurement of NO_2

The fluorescence intensity and the signal decay curve of NO_2 are measured at different gas pressures as a function of excitation photon wavelength in the range of 460 to 510 nm using an excimer laser pumped dye-laser. The fluorescence of NO_2 at different wavelengths shows cascading feature, crossing through two intermediate states before decaying to the ground state. This is evident from the departure from single-exponential nature of the decay curve obtained in the present experiment. A multi-exponential, non-linear fitting of the decay curve indicates the existence of three life time viz. 3, 30 and 70 μs, for the band fluorescence of the undispersed NO_2 fluorescence and having no dependence on excitation wavelength. The excitation spectra of NO_2 at different gas pressures have been measured to study the effect of collisional quenching on the measured radiative life time using the time-resolved records of the decay curve at different excitation wavelengths and at different gas pressures.

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

PLANETARY/COMETARY ATMOSPHERES

Polar Ion Exosphere of Mars

The model developed earlier to study the flux and density of O^+ escaping from the nighttime ionosphere towards the Martian magnetotail is extended to calculate the mean velocity along the magnetic field lines between 200 km and 8000 km, in the dayside and nightside of the ion exosphere at exospheric plasma temperatures 1000K, 1500K and 2000 K. The mean velocity **(Fig. 4.8)** varies from 3 m/s to 1 km/s at these temperatures. According to Phobos 2, observations the speed of O^+ is of the order of 1 km/s in the magnetotail lobe while the plasma sheet is charcterized by accelerated beam upto 200 km/s. These discrepancies could be due to the non-inclusion of all the possible means of outflow of plasma such as the outflow from the magnetosheath to the plasma sheat. The charge separation electric fields at the dayside and nightside are of the same order and model estimation of the same at the exobase are found to be 0.70, 0.85 and 1.0μV/m for 1000 K, 1500 K and 2000 K respectively.

(S.A. Haider)

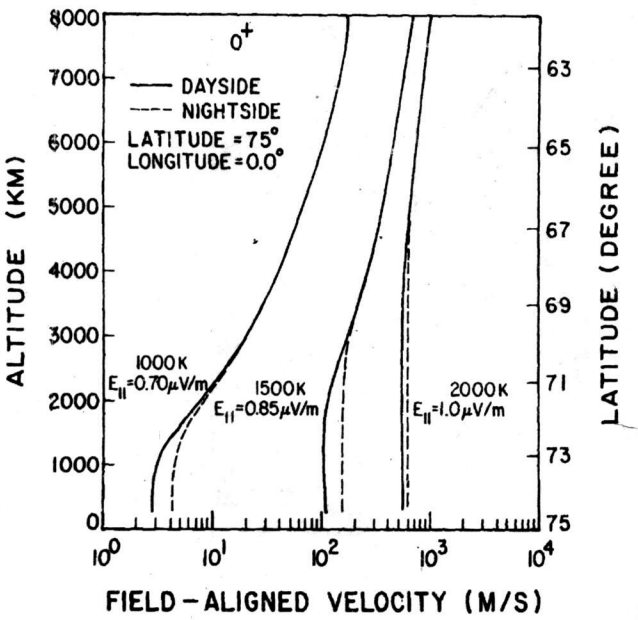

Fig. 4.8 : Mean velocity profiles of O in the dayside and nightside exosphere at exospheric plasma temperatures 1000 K, 1500 K and 2000 K for parallel electric fields 0.70, 0.85 and 1.0 μv/m respectively.

Chemistry of Nighttime Ionosphere of Mars

Though there are no explicit observations of the ion composition in the nightside ionosphere of Mars, O^+_2, NO^+, CO^+_2, O^+, N^+_2, CO^+ and H^+ ions are expected to be present according to the existing theories. The steady state photochemical equlibrium of these ions are studied using analytical yield spectrum approach and continuity equations. Various production processes such as magnetotail electron impact ionization, charge exchange processes of various ions with the neutrals are included along with the dissociative recombination loss process in the analysis. The investigation revealed that O^+_2, NO^+_2 and CO^+_2 are the major ions in the nightside ionosphere of Mars.

(S.A. Haider)

Investigation on the Composition of Halley Comet

One of the major results of Giotto mission to Comet Halley is the observation of an unexpectedly abundant C^+ ion which could not be explained only due to photon impact dissociative ionization process of CO, CO_2 and CH_4. The observation requires the additional source of atomic carbon. To resolve the carbon crisis in the coma of the Comet Halley, the production and loss of atomic carbon ions due to different sources of Ionization have been investigated. The theoretical investigation suggests that the crisis can be resolved with the inclusion of the production of carbon bearing ions by the auroral electron precipitation of solar wind origin, as one of the possible sources.

(S.A. Haider)

OCEANOGRAPHY AND CLIMATE STUDIES

The research programmes of the Oceanography and Climate Studies Area centered around (i) retrieving past environmental and climatic information through multiproxy mapping of a variety of continental and oceanic archives (ii) characterizing the circulation of water and air-sea exchange of gases in the Arabian Sea and (iii) basic and applied hydrological problems.

Palaeoclimate and Palaeoenvironment Studies

Deserts and Desert Deposits

A new initiative was launched as a major project in the Thar desert to understand its evolution in relation to regional and global climate change. As a part of this programme, detailed logging of sand profiles at Chamu, Beri and Amarsar was done and their ages determined using TL and IRSL methods. The results yield ages of upto

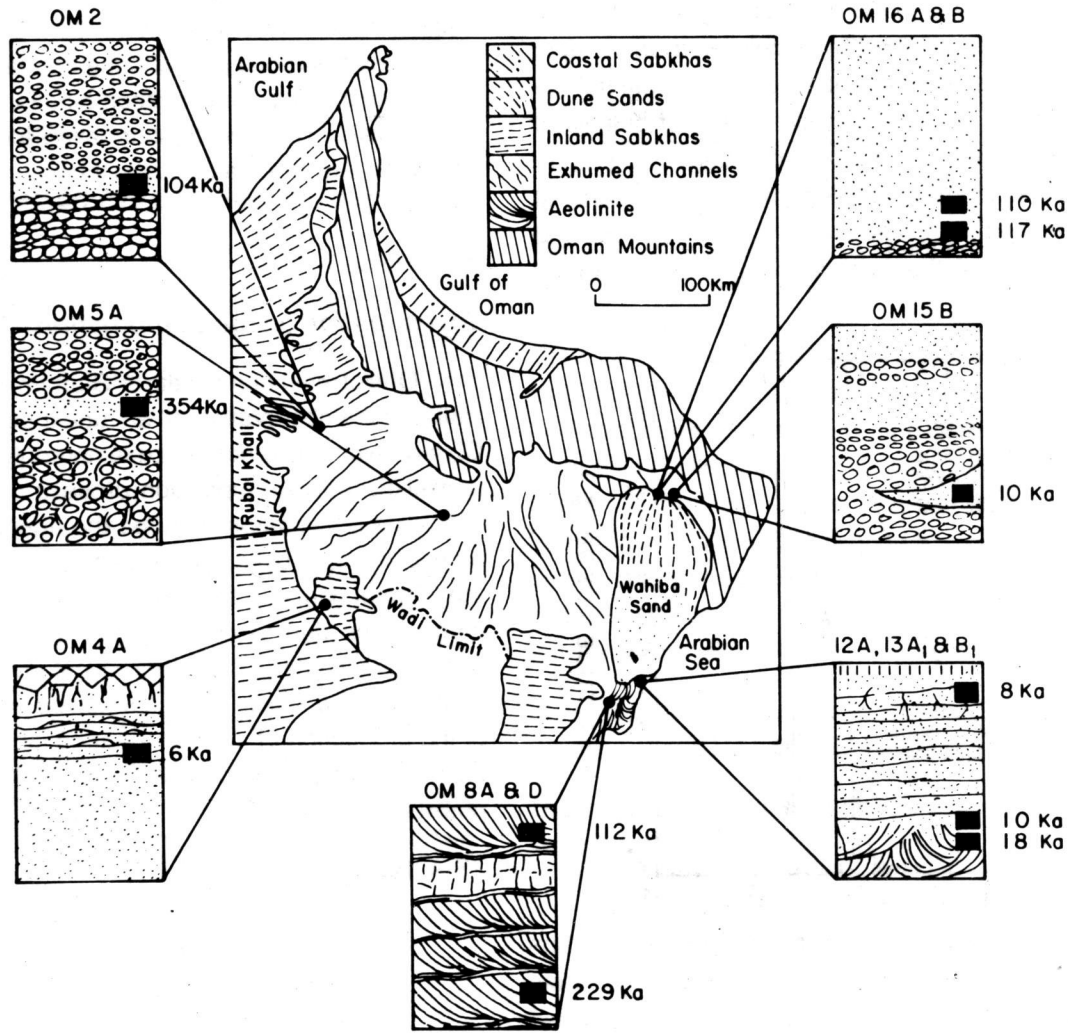

Fig. 5.1 : Map showing various Quaternary deposits of Oman which have been dated with luminescence technique.

100 ka providing evidence of antiquity of aeolian accumulation at these sites. The IRSL ages on a dune sequence at Bikampur indicate that the most recent accumulation phase ended approximately 1 ka ago which could be the terminal age of desert sand accumulation in this region. This project is funded by the DST and is a joint study among PRL, CAZRI, Deccan College, BARC and Delhi University scientists.

Luminescence and ^{14}C dating together with sedimentological studies of alluvial flood plains from Ghaggar and Chautang have been carried out to determine periods of changing alluvial /aeolian activities and their relation to climate. The results show : (i) termination of alluvial activity at ~ 50 ka, (ii) reduction of alluvial activity and increase in aeolian activity between 50-20 ka, (iii) strong aeolian activity around 20-13 ka and (iv) sudden increase in alluvial activity at ~ 13 ka. These data provide evidence for a more humid climate before 50 ka and after 13 ka. These inferences are consistent with available data on SW and NE monsoon variations in the past.

Last year we had developed a method for dating pedogenic carbonates based on luminescence principles. Using this method we have determined the ages of several carbonate horizons contained in the sand profiles of Thar. The results indicate the possibility of a regionally extensive episode of soil carbonate deposition at 17 ± 3 ka. Determination of these chronologies are important as these carbonates can serve as stratigraphic markers and palaeomonsoon indicators.

The first phase of study to document climatic change recorded in the sand profiles of the Oman and Rub Al Khali deserts was completed .The first event chronostratigraphy of this region has been established **(Fig. 5.1)** based on luminescence dating. The aeolianites have been dated to be ~ 230 ka and that the deposition occurred with brief hiatuses till ~ 112 ka. The earliest age of the Wahiba sand is ~ 120 ka indicating a lower limit for the age of the Oman desert. On a more recent time scale studies of 'sabkhas' and lake deposits show evidence of more humid climate at ~ 8 ka in this region.

Relict Sediments from Spiti Valley

Dating of seismites (i.e., buried sediments that suffered structural deformation due to tectonic events when at the sediment water interface) from Spiti valley based on TL was continued to determine the repeat frequency of seismic events in the region.

The results show regionally extended tectonic activity at ~ 40 ± 8 ka in the Nainital, Lamayuru, Spiti and Mohand regions. It is likely that these tectonic events have influenced the formation of the lakes in these regions (viz. Nainital, Lamayuru etc). The repeat frequency deduced from the above ages centre around ~ 3.5 ka.

The proper application of luminescence method of dating environmental samples requires better understanding of some of basic processes associated with the method. In this context, methodological studies on the dependence of the precision in the estimation of equivalent dose (D_e) on various experimental parameters such as maximum dose applied (D_{max}), the distribution of dose points, the number of data points, etc., were examined by generating a large number of growth curve data sets through a monte carlo simulation. For example, for a saturating exponential growth curve with 5% experimental scatter, a precision of 7% on D_e can be obtained for $D_{max} \geq 6D_e$.

(D. Banerjee, C. Felix, N. Juyal, S. Kusumgar, K. Pande, R. Ramesh, A.K. Singhvi and M. Someshwar Rao)

Glaciological Studies

The depositional history of the snow-fed-lake, Kassojan, from north Sweden was studied. The sediments have varves of 0.5 mm thick throughout its length, which established its chronology for the past ~ 700a . ^{210}Pb and ^{137}Cs have been measured in the top sections spanning past several decades. The sedimentation rate derived from the radionuclide profiles is ~ 2 mm/a a factor ~ 4 higher than that derived from varves ~ 0.5 mm/a. The cause for the discrepancy between the results is currently being analyzed.

Taking advantage of the fact that the Kassojan lake sediments contain significant amount of biogenic

silica and that the varve chronology extends to~700a they were used to determine the half life of ^{32}Si. The $^{32}Si/SiO_2$ activity ratio of biogenic silica recovered from the different layers of the lake sediment decrease with depth which translates into a half life of (178 ± 10) a for ^{32}Si. This value compares very favorably with recent direct and indirect (geochemical) measurements which vary from 100-200a . This work was carried out jointly with Prof. F. Oldfield of the University of Liverpool, UK.

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

Quaternary Glaciation in the Himalaya

To reconstruct the regional snow line depression during the Quaternary, we have extended our study in the Alaknanda and Dhauliganga basin of the Central Himalaya. We have been able to delineate three glacial advancements which are in conformity with our observations made last year in the Goriganga basin. Attempts are underway to ascertain their precise equilibrium line altitudes (ELAs). The geomorphological evidences in the form of lateral moraines indicate that the extent of valley glaciation in this region during the Quaternary had reached upto 3000 m. A 10 m thick laminated (varve?) deposit has been located in the Dhauliganga basin. The deposits are underlain by the terminal moraine and truncated by the outwash deposit. Individual layers are 5 to 10 cm thick and invariably separated by a pale yellow oxidised layer. The deposition which appears to have taken place during the glacial climate is controlled by rate of ice melting during summer and winter. Chemical and isotopic studies of the layers are being carried out to characterise the depositional processes leading to the formation of these sediments and to assess their utility to yield climatic and environmental information.

(S. K. Bhattacharya, P. Ghosh, N. Juyal and R.K. Pant)

Nal Sarovar Studies :

Nal Sarovar (22°48'N, 72°E), a large (~120 km^2) shallow lake (maximum depth 3 m) lies in the middle of the Nal depression linking the Gulf of Kutch to the Gulf of Cambay. The region is also located within the palaeodesert margin bordering the Thar desert. Four years ago we had collected a 54 m long core from the Nal Sarovar for the reconstruction of palaeoclimatic, eustatic and tectonic history of the region, based on a multidisciplinary approach involving remote sensing analysis, lithological correlation, sedimentological and mineralogical characterization, isotopic studies, and radiocarbon and lumines-

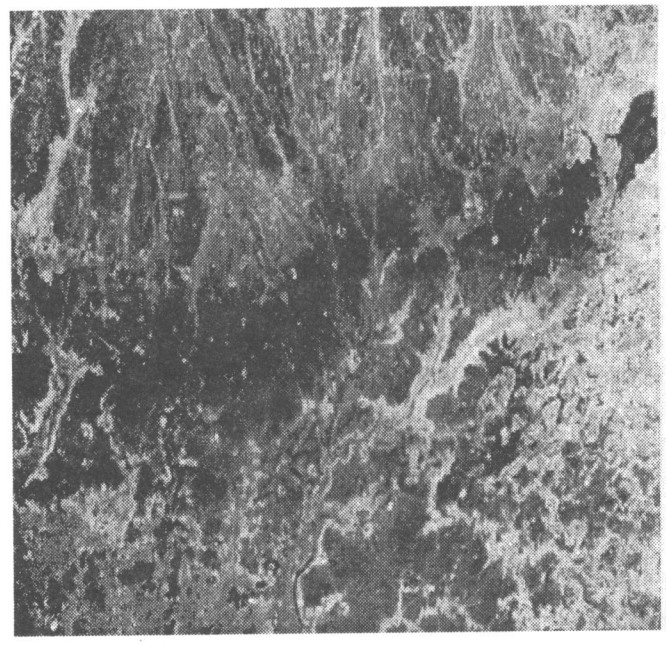

Fig. 5.2 : Satellite imagery of Nal Sarovar region showing inland deltas, zone of terminating streams and mudflats (MIRM 2). Satellite imagery (top), interpretation. (bottom)

cence dating. The results have yielded important information on the evolutionary history of Nal Sarovar and the palaeoclimate of the region.

The Nal Sarovar seemed to have evolved in three stages. During the last major interglacial when the sea level was higher, a shallow sea would have linked the Gulf of Cambay with the Gulf of Kutch. The palaeo-deltas and the palaeo-strandline **(Fig.5.2)** observed to the west of Nal Sarovar were formed during this period. The clay mineralogy of the sediments in the 18-54 m horizon of the core suggests that the sediment input at the present location of the Nal Sarovar from the eastern (mainland Gujarat) side was small. With the lowering of sea level, the deposition of fluvial material from the east advanced westwards, as indicated by the presence of a thick layer (5-35 m) of sand, with heavy mineral assemblages characteristic of source from the east. The deposition of sand was not continuous as indicated by the presence of red beds and evaporite minerals. As a result of the combined influence of west ward advance of the sedimentation front, tectonism and the post glacial sea level rise, the elevation of the Nal Sarovar came to within few metres of its present position at about 7 ka when it became a closed basin. The present Nal Sarovar, therefore, originated as a result of westward advance of the sedimentation front until it could no longer advance due to the presence of high land of Saurashtra.

The $\delta^{13}C$ and C/N ratio in the topmost organic mud horizon that was deposited in the Nal Sarovar basin provide a qualitative picture of the palaeoclimatic variations in the region similar to the one deciphered by earlier workers from the Rajasthan lakes except for an additional, short dry episode at ~ 5 ka recorded at Nal Sarovar.

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

Peat Deposits

Few years ago, we had demonstrated that the carbon isotopic variations in peat deposits from Nilgiris, South India reflect the variations in palaeo-monsoons during the last 20,000 years. We have subsequently analyzed the oxygen isotopic composition of these peat samples. The results show that tropical India was cooler by 4 to 5°C during the Last Glacial Maximum (LGM) (about 18,000 years ago) relative to present day climate. Our results also confirm aridity during LGM and intense monsoon at ~ 10,000 years before present. The record has been extended farther back in time to 40,000 years and more peat cores have been analyzed to verify the geographical extent of the palaeoclimatic changes. This work was done in collaboration with scientists from the Indian Institute of Science, Bangalore.

(J.T.Padia, R.K. Pant and R. Ramesh)

Limestones from Central and Western India: Palaeoclimate during Cretaceous

The Bagh Group of rocks from central and western India represent a large stretch of sedimentary sequence belonging to the Upper Cretaceous period which are overlain by the continental Lameta deposits. We carried out carbon and oxygen isotope analysis of the carbonate phase of the Bagh Group to gain understanding of the environment of their deposition and to obtain data for the reconstruction of global palaeoclimatic scenario at the terminal Cretaceous period.

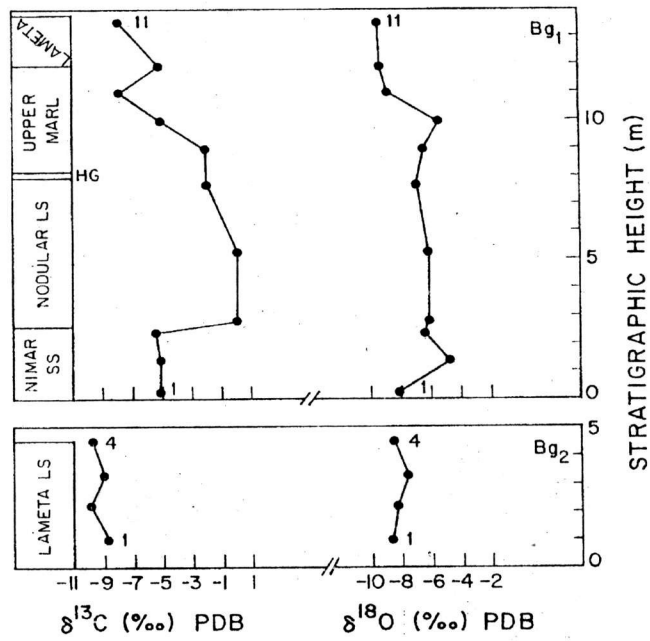

Fig. 5.3 : $\delta^{13}C$ and $\delta^{18}O$ variations in Bagh Group carbonates and lametas from western and central India.

The isotopic data for the first four sections are shown in **Fig. 5.3.** Different formations are characterised by different $\delta^{13}C$ values whereas there is overlap in $\delta^{18}O$ values. Some of the highly negative $\delta^{13}C$ values of the Nimar sandstone and the Lametas establish that they were derived from fresh water systems. For the Lametas this conclusion is consistent with our earlier study which showed that they were greatly altered by pedogenic processes and their carbon isotope values reflect contribution from vegetational sources (C_4 plants). The $\delta^{18}O$ values for samples from any one formation are highly variable indicating post-depositional diagenesis.

The nature of the transition from the fresh water regime of the Nimar sandstone to the marine regime show that the marine transgression was quite rapid and occurred in a single stage. In contrast, marine continental transition was slow and probably characterised by a fluctuating marine regression phase. This study was carried out in collaboration Mr. S.C. Tripathy of GSI, Lucknow.

(S.K. Bhattacharya and R.A. Jani)

OCEANOGRAPHY

The major activities in oceanography during the year were (i) water circulation in the Arabian Sea (ii) air-sea exchange of gases (iii) radionuclides in the water column of the Arabian Sea (iv) atmospheric deposition of nutrients to the Arabian Sea surface. Some of these programmes are supported by the Department of Ocean Development.

Ra Isotopes in the Surface waters of the Bay of Bengal

Last year we reported the distribution of Ra isotopes in the coastal and open ocean waters of the Bay of Bengal and the inverse relation of ^{228}Ra to that of salinity. Very recently, it is reported that the discharge of groundwaters could be an important component of Ra isotope budget in coastal waters. The extrapolation of the inverse trend between ^{226}Ra, ^{228}Ra and salinity to fresh water salinity values yield Ra isotope concentrations significantly more than those measured in the Ganga, Brahmaputra and Hoogly river systems. This result can arise either due to discharge of groundwaters into the Bay with high Ra

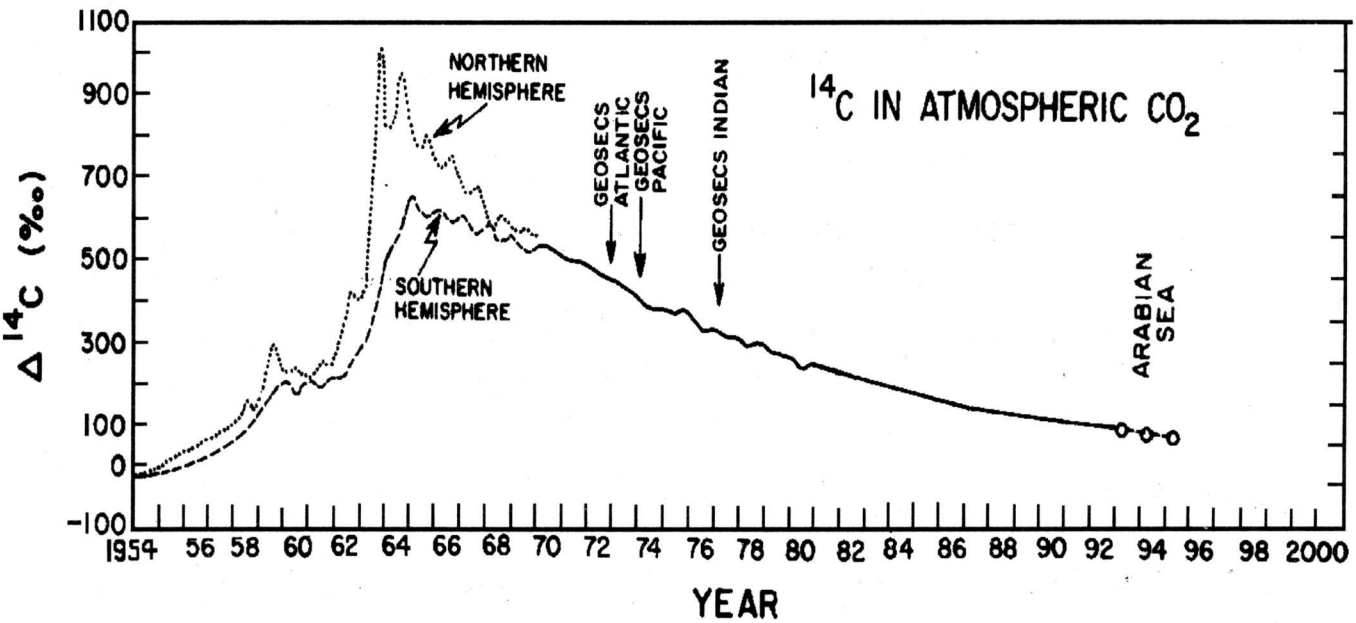

Fig. 5.4 : Radiocarbon activity in atmospheric CO_2 since 1956. The high $\Delta^{14}C$ levels of 1000 % in 1963 resulting from nuclear weapons tests has decreased to ~ 110 by 1995. The decrease yields a mean life of ~ 15 years for bomb ^{14}C in the atmosphere.

isotope concentration or due to desorption of Ra from river sediments at low salinities. Experiments are underway to choose between the alternatives.

The lateral eddy diffusivities have been deduced from the Ra isotope data to be of the order of 10^6 cm^2sec^{-1} in the Arabian Sea and the Bay of Bengal. These data help in the modelling of the dispersal of pollutants/industrial effluents into the coastal seas. The derived eddy diffusivities are compatible with the coastal circulation model proposed for the Bay of Bengal.

Radiocarbon in Air over the Arabian Sea

Measurements of radiocarbon in air over the Arabian Sea and in the water column were made to assess the air-sea exchange time scales and water circulation characteristics in the region. During the three years of collection (1993-95) the mean $\Delta^{14}C$ value of air over the Arabian sea varied from (120 ± 6) ‰ in 1993 to (110 ± 5) ‰ during 1995.The $\Delta^{14}C$ in atmospheric CO_2 ,was ~ 1000 ‰ in 1963 due to nuclear weapons testing **(Fig. 5.4)**, which has been decreasing steadily due to its exchange with the oceans and biosphere. The values measured for marine air over the Arabian Sea, if typical of northern hemisphere yield values of ~ 15 years for the mean life of bomb ^{14}C in the atmosphere.

^{234}Th Scavenging and Particle Export Fluxes in the North Eastern Arabian Sea

The particle scavenging rates, export fluxes of ^{234}Th and of settling particles in the upper 100 m column of the Arabian Sea have been determined as a part of the JGOFS (India) programme. The spatial and temporal measurements of dissolved ^{234}Th-^{238}U disequilibria made in the north-eastern Arabian Sea reveal close similarities suggesting that the rates of particle-associated scavenging processes are generally uniform in this region. The observed disequilibrium, when integrated for the surface 100 m, yields a mean scavenging residence time of ~ 30 days for dissolved ^{234}Th and a removal rate of ~ 1700 dpm $m^{-2}d^{-1}$.

The deficiencies of total ^{234}Th relative of ^{238}U allow us to compute the ^{234}Th export fluxes. Our flux data show spatial variations with enhanced export fluxes centered around 22°N 67°E, a region characterised by higher rates of column primary productivity. Using the ^{234}Th export fluxes and the measured specific activity of ^{234}Th in the sediment traps, we have computed the particle and carbon fluxes at 100 m. These results suggest that nearly 30% of the total production is exported via sinking particles in the north-eastern Arabian Sea.

Atmospheric Deposition Fluxes of Nutrients Over the Arabian Sea

^{210}Pb (22.3 a. half-life) is a radioactive nuclide which is continuously produced in the atmosphere by the decay of gaseous ^{222}Rn (3.8 days half-life) emanating from soils. Being chemically reactive, ^{210}Pb rapidly attaches to the ambient aerosol and is principally removed from the atmosphere, not by radioactive decay, but by the deposition of its aerosol carrier. Thus, the deposition flux of any aerosol-associated chemical species to the ocean surface can be determined from the ratio of the species to ^{210}Pb in the aerosol and the deposition flux of ^{210}Pb in the surface ocean.

Recently, there has been considerable interest in the atmospheric supply of nutrients viz. PO_4 and NO_3 to the sea. It has been suggested that the episodic inputs of these species via atmospheric deposition may have a significant influence on marine biological productivity. As a part of the JGOFS (India) programme, we have initiated a systematic study to measure the atmospheric deposition fluxes of nutrients (PO_4 and NO_3) to the surface waters of the north-eastern Arabian Sea and to assess their role in contributing to surface productivity.

Bulk aerosol samples were collected on board ORV Sagar Kanya during three cruises using high volume air sampling system. Sections of each filter are analyzed for concentrations of ^{210}Pb, NO_3 and $PO_4$and water-soluble sea salt ions. The NO_3 concentration in the samples range between 4 to 66 $\mu m/10^3m^3$ with lowest values during the SW monsoon season. The NO_3 concentration shows, a positive correlation with ^{210}Pb indicating a continental source for NO_3. The deposition fluxes of NO_3 centre around 20μm m^{-2} d^{-1} significantly lower than that supplied from upwelling of deeper waters to the euphotic zone (~ 1000 μm m^{-2} d^{-1}).

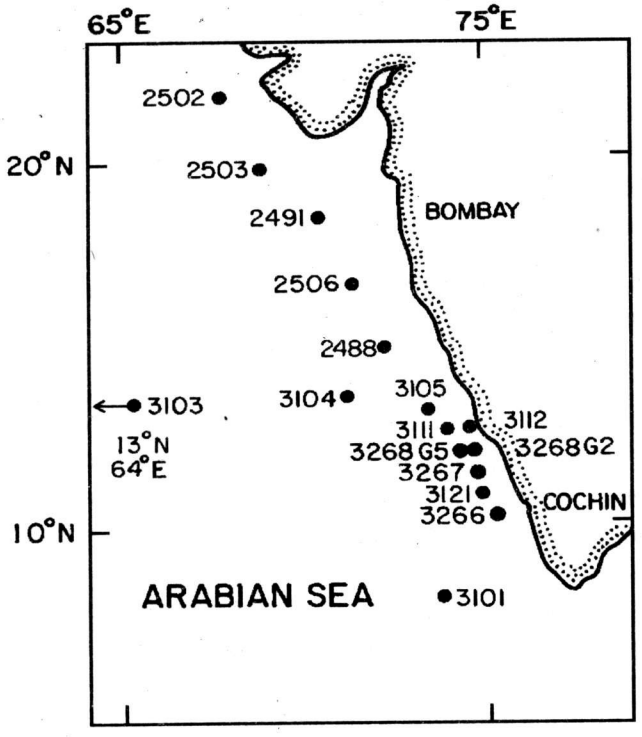

Fig. 5.5 : Locations of gravity cores collected for retrieving palaeoenvironmental and palaeoclimatic information.

Palaeoceanography from the Arabian Sea Sediments

As a part of ISRO-GBP and JGOFS (India) programmes we have initiated a major study to decipher past environmental/climatic changes in the Arabian Sea, especially in the north eastern region which houses a perennial denitrification layer in the intermediate depths. The study is based on the distribution of suite of chemical elements, which serve as proxies for productivity and redox conditions, in undisturbed gravity cores from the continental margins of western India. Towards this, over the past about three years (1992-95) , a total of 15 gravity cores ranging in length from 0.8 - 2.0 m were collected onboard the DOD ship ORV Sagar Sampada. The locations of the cores are given in **Fig. 5.5**. These cores after determining their accumulation rates are being analyzed for CaCO3 stable isotopes ($\delta^{18}O$ and $\delta^{13}C$) on select species of foraminifera, Ba, Sr, Cd, V, orgC, biogenic Si, clay minerals and Mn, Fe,Al and U.

(R.Bhushan, S. Chakraborty, M. Dixit, S. Krishnaswami, R. Ramesh, R. Rengarajan, M.M. Sarin, Charu Sharma, S.K. Singh and B.L.K. Somayajulu).

HYDROLOGY

Water Budget of Monsoon Rainfall and Evapotranspiration

Last year we initiated a major programme to assess the water budget of monsoon rainfall and the role evapotranspiration in contributing to the water budget. These studies were continued on the ground water samples collected from the southern and western regions, between Gujarat and Kerala. Stable isotopic studies indicated three zones of groundwater with $\delta^{18}O$ varying from -3‰ to -2‰ the more depleted values indicating rain water as the source. More groundwater samples have been collected in the Hyderabad - Rameswaram - Vijayawada triangle. Analysis are in progress.

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

Stable Isotope Studies on Amba Dongar Carbonatites

We have completed the stable isotope analysis of carbonatite samples from one of the largest Indian carbonatite bodies, Amba Dongar, Gujarat. In addition, Sr isotopic compositions have also been measured. The results from the different carbonatite varieties and alkaline rocks associated with them lead to the following conclusions. (i) two generations of calcio-carbonatites with distinct initial carbon isotopic compositions have been identified. This reflects mantle heterogeneity in carbon. Sr isotope data suggest that the samples have not suffered crustal contamination during their emplacement. (ii) a two component Rayleigh fractionation model developed by us earlier can satisfactorily explain the carbon and oxygen isotope variations in calcio-carbonatites. (iii) fluid-rock interaction model calculations reveal that the ferrocarbonatites were formed at 400°C. (iv) the secondary alteration observed in some of the carbonatites is due

to interaction with the fluid which was responsible for the fluorite mineralisation in this area.

(K. Pande, R. Ramesh, J.S. Ray and J.R. Trivedi)

Isotopic Study of Uraniferous Dolostones from Cuddapah Basin, Southern India

Recently, carbonate-hosted uranium mineralisation has been discovered in the Vempalle Formation of Cuddapah Supergroup in South India. To get further insight into the physicochemical conditions of uranium precipitation and the environment of deposition of the dolostone, we have analyzed carbon and oxygen isotopic ratios of carbonate phases from three uranium prospects. In addition, uranium activity ratio, $^{234}U/^{238}U$ was also determined in a set of samples from each prospect to assess the extent of chemical weathering of the uranium minerals.

The variation of $\delta^{18}O$ in the Cuddapah dolostone closely resembles those reported in other Pre-Cambrian dolomite provinces i.e. a wide scatter in $\delta^{18}O$ and less scatter in $\delta^{13}C$. The clustering of $\delta^{13}C$ values (0.1‰ and -0.9‰) reflects their marine origin which is supported by the oxygen isotope ratios. The reported mean $\delta^{18}O$ value of Pre-Cambrian carbonates is about -7‰ . The majority of the $\delta^{18}O$ values in the present study (-7.2 to -9.2‰) are close to this mean confirming their marine origin. The nature of the alteration suggests that the diagenesis was mediated by fresh water interaction in which the change in carbon isotope ratio is either negligible or slightly negative but the change in oxygen isotope ratio is large and negative.

The $^{234}U/^{238}U$ activity ratio in most of the samples is close to unity as expected for rocks older than 1ma. However, a few samples with high uranium, have activity ratio close to 0.7. This indicates preferential leaching of ^{234}U by acidic or alkaline waters under oxidizing conditions. This leaching must be recent or an ongoing process, since the half-life of ^{234}U is only 2.4×10^5 a. The lack of correlation between low U-ratio and low $\delta^{18}O$ values suggest that the diagenetic alteration of oxygen isotope occurred much earlier in the geologic history.

(S.K. Bhattacharya, M.M. Sarin and R.A. Jani)

Radiocarbon Dating Laboratory

The radiocarbon laboratory which acts as a National Facility dated ~ 60 samples during the year. Some of the important results pertain to river migration in the past, chronology of speleothem etc.

It is possible to date past flow patterns of a river by identifying the palaeo-channels of river meandering and dating the carbon containing material in them using ^{14}C. Studies conducted on the Cauveri basin suggest that the river has been flowing the same way since the past ~ 2600a. Another palaeochannel of the same river near Dharampur is be dated to 1500a. This work was carried out in collaboration with Dr. S.M. Ramswami of the Bharathidasan University.

Speleothems are calcium carbonate deposits formed due to slowly dripping ground water from the cave roof. These deposits are promising source of past climatic record of the area. From the analysis of two stalactite samples from Mowsmai cave in Cherrapunji and Gupteswar cave in Orissa, we conclude that the ground-water precipitating in these stalactites are experiencing a partially closed system-dissolution-process. Further work is going on to assess the possibility of using radio-carbon dating method in these samples.

To understand the development of anoxic conditions, sea level changes and/or burial due to tectonic activity, selected peat samples, from Kerala coast have been dated, which yild ages of 6.7-7.5 ka, 25ka and > 35ka . This work is being carried out in collaboration with K.P. Shajan of the Cochin University.

Recently, a chalcolithic (copper stone) site 'Balthal' has been unearthed in Udaipur district, Rajasthan. There is evidence of cultural similarity between Balthal and the late Indus or Harappan settlements as observed in the large and complex structures made of stone and mud bricks, shapes and design of ceramics, copper bronze tools and ornamental beads. This suggests that the inspiration for founding the Balthal settlement came from the Harappan people of Gujarat and that some of the early settlements may have been migrants from that region. Radiocarbon dates based on seven charcoal samples

analyzed in the radiocarbon laboratory show Balthal as the oldest known village settlement in India, outside the zone of the Harappan civilization. These dates range from 4300 to 1800 yr B.P. It establishes the founding of the first settlement to more than 4000 years ago and its abandonment around 1800 years ago.

(S. Kusumgar and M.G. Yadava)

ICP-AES Facility :

An Inductively Coupled Plasma-Atomic Emission Spectrometer (Jobin-Yuvon, Model 38 S) was procured and installed during the year **(Fig. 5.6a)**. Resolution and sensitivity tests and calibration of the instrument have been carried out. An excellent resolution of 0.004 nm for the quadruplet emission lines of iron at 310.010 nm with a 3600 groove/mm grating is achievable on our instrument **(Fig. 5.6b)**. Typical detection limits measured in our laboratory for the elements are : Pb (220.353 nm, 10.6 ppb), Co (228.616 nm, 0.6 ppb), Cr (267.716 nm, 0.8 ppb), Cu (324.754 nm, 0.4 ppb) and Al (396.152 nm, 0.8 ppb). Results of measured concentrations of Fe in geochemical standards along with the recommended values are shown in **(Fig. 56c)**. The instrument will be used for the measurements of major and minor elements to characterise geological and environmental samples.

(M.M. Sarin)

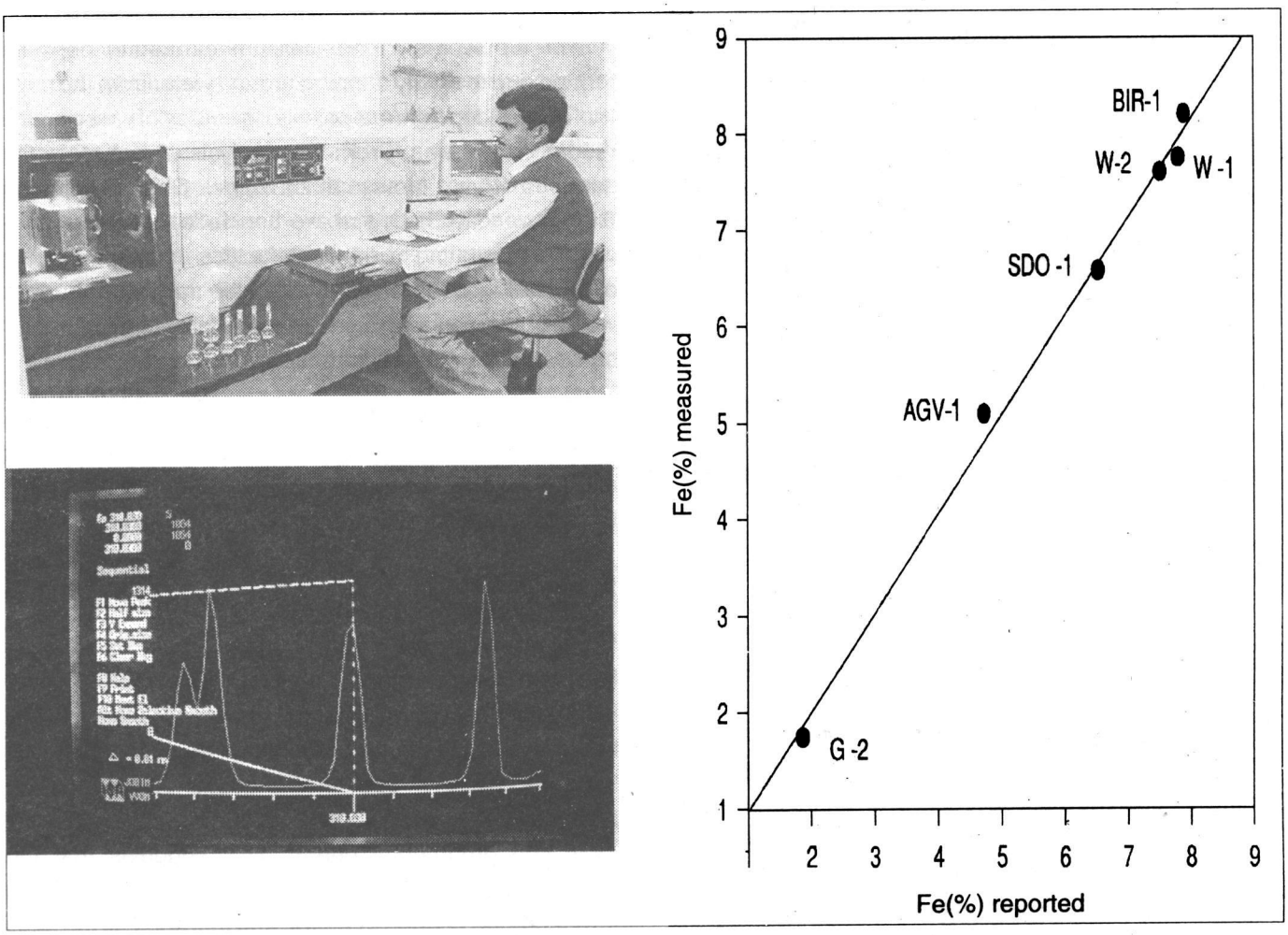

Fig. 6 : (a) ICP-AES unit (b) separation of quadruplet lines of Fe at 310.01 nm (c) comparison of Fe concentrations measured using ICP-AES with reported values.

Solar System and Geochronology

The researches in the solar system and geochronology area center around the topics of the early evolution of the solar system, interactions of cosmic rays with meteorites, chronology of the major geological formation in the Indian subcontinent and geochemical investigations related to the cause(s) of the boundary extinction. Some of the important studies carried out during the year include, radionuclide and stable isotope records in specially selected meteorites, ^{39}Ar-^{40}Ar chronology of the Deccan province, $^{206}Pb/^{207}Pb$ dating of single zircon from the Singbhum Craton and radiochemical neutron activation studies of K/T boundary samples from Anjar in west Gujarat.

Evidence for Gleissberg Minima in Sunspot Cycles based on ^{44}Ti in Meteorites

An evidence for strong relaxation of heliospheric magnetic field during long solar quiet periods was found from study of cosmogenic ^{44}Ti in chondritic meteorites. The heliospheric magnetic field is controlled by the solar activity, as established by measurements over the past few decades, but its characteristics when the Sun was quiet for prolonged periods, such as during Gleissberg or Maunder minima, has been a matter of debate. Cosmic ray produced ^{44}Ti in meteorites, provides a monitor of the galactic cosmic ray (GCR) flux and allows estimation of the modulation effect of the Sun for the period 1883 to 1992. The measured ^{44}Ti activity in meteorites, specially selected for this study, is consistent with the expected value, but the increase, during the last Gleissberg minimum, is four times greater than expected for a GCR modulation based solely on sunspot numbers. This result implies that the heliospheric magnetic field was weaker than at present and as a result the GCR flux (for energy greater than 1 GeV) was higher, between 2.2 to 3.6 protons/cm^2.sec.4πsr at 1 to 3 AU during solar cycles 12 to 15, than its contemporary average value of ~1.7 protons/cm^2.sec.4πsr. This work was done in collaboration with the Istituto di Cosmogeofisica,Turin, Italy.

(N.Bhandari, K.M.Suthar, G.Cini Castagnoli, C.Taricco and G.Bonino)

^{36}Cl in the Early Solar System

The recent discovery of the extinct nuclide ^{41}Ca mean life (τ=0.15 Ma) in Ca-Al-rich Inclusions (CAIs) from the Efremovka meteorite reported by us strongly suggested the possibility that ^{36}Cl (τ = 0.43 Ma) could also be present in this meteorite. This motivated us to analyse samples of this meteorite to look for excess ^{36}Ar that may be related to the in situ decay of ^{36}Cl. The total ^{36}Ar in a meteorite sample is a mixture of at least two components: a trapped component and a cosmic ray produced (cosmogenic) component. The cosmogenic component is again the sum of two components, the spallation component produced by direct interactions of energetic cosmic ray protons, and the neutron induced component produced by cosmic ray secondary neutrons. In addition, the decay of now-extinct ^{36}Cl, if initially present, results in a pure ^{36}Ar component. Ar isotopic data alone do not allow a resolution of all these components, but measurement of Ne and Xe alongwith Ar in the sample, in a stepwise temperature extraction of gases will aid in resolving the various Ar components.

We have measured Ne, Ar and Xe isotopic compositions in two matrix (fine-grained silicates) samples and two CAIs from Efremovka, as well as in a matrix sample of Allende, another primitive meteorite, to look for excess ^{36}Ar. (**Fig. 5.7**) is a plot of the measured $^{38}Ar/^{36}Ar$ ratio during stepwise temperature release performed for all the samples. The dotted line in each panel is the expected normal trapped ratio. Any value of $^{38}Ar/^{36}Ar$ above this indicates presence of a spallation component, while a lower value indicates presence of excess ^{36}Ar. It can be seen that matrix samples of Efremovka and Allende do show excess ^{36}Ar, while no apparent ^{36}Ar excess is evident for CAIs of Efremovka. We now use the Ne and Xe isotopic data respectively to estimate the ^{36}Ar amount due to normal spallation and due to insitu $^{35}Cl(n,\gamma)^{36}Cl(\beta-)^{36}Ar$ reaction. After accounting for these components the remaining Ar should represent a trapped component ($^{38}Ar/^{36}Ar$ = 0.188) and an extinct ^{36}Cl component, if present, with $^{38}Ar/^{36}Ar$=0.

The Ar data of Allende do not indicate any excess ^{36}Ar due to ^{36}Cl decay, while the matrix samples of

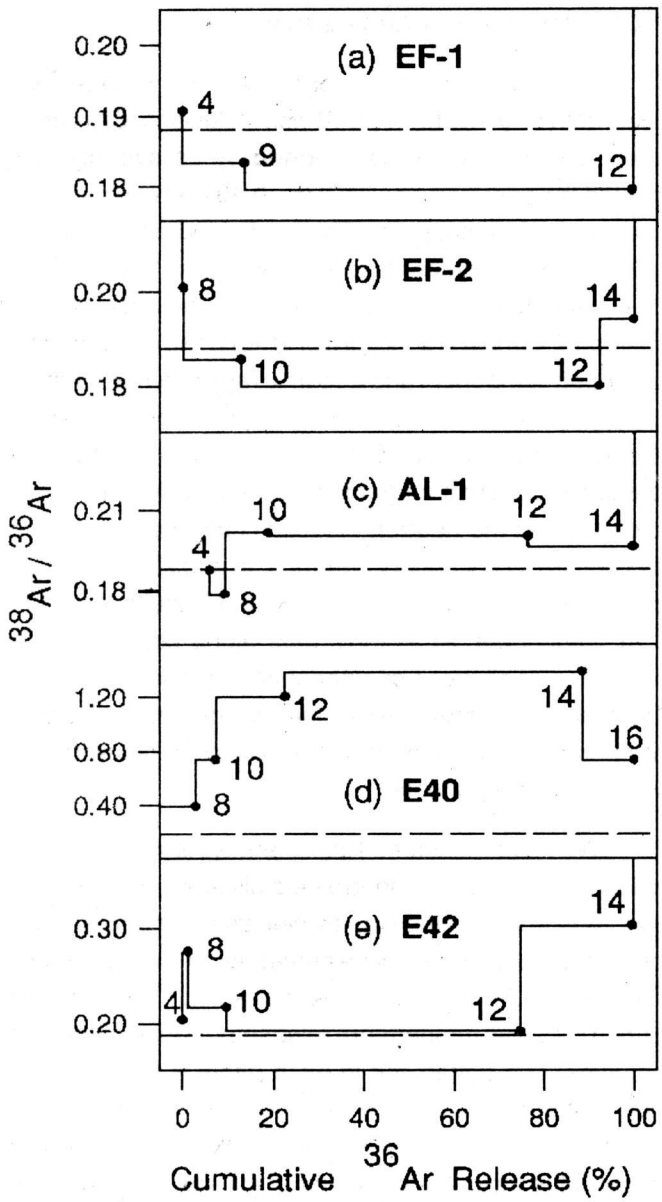

Fig. 5.7 : Release pattern of $^{38}Ar/^{36}Ar$, plotted against cumulative ^{36}Ar released, for matrix samples of Efremovka (figs. a, b), and Allende (figs. c, d) as well as for two Efremovka CAIs (figs. e, f). The dotted line in all the panels represents the trapped $^{38}Ar/^{36}Ar$ component. Release temperature in hundreds of degree centigrade is indicated for all the data points.

Efremovka show a huge excess of about 10^{-7}cc STP/g of ^{36}Ar that can be attributed to the decay of extinct ^{36}Cl. We can derive an initial $^{36}Cl/^{35}Cl$ value of ~10^{-6} at the time of formation of the fine grained silicates that constitute the Efremovka matrix material. If we consider nucleosynthetic yield of ^{36}Cl from a supernova or a TP-AGB star and assume either of them to be responsible for injecting live ^{36}Cl into the solar nebula, the initial value derived by us suggest a timescale of ~1 Ma for the formation of some of the first silicate grains in the solar system following the collapse of the solar nebula. This value is consistent with the result obtained earlier by us based on the presence of ^{41}Ca in the same meteorite. This work was carried out in collaboration with the Vernadsky Institute, Moscow, Russia.

(S.V.S. Murty and J.N. Goswami)

Cosmogenic Records in Efremovka CV3 Meteorite

The Efremovka meteorite is a find with a recovered mass of 21 kg. Petrologic and chemical studies suggest Efremovka to be the most pristine member of CV3 group of meteorite, with very little secondary alteration of its matrix and CAIs. We have found signatures of the short-lived isotopes, ^{26}Al, ^{41}Ca and ^{36}Cl in this meteorite that clearly attest to its pristine nature. The objective of our study was to decipher the cosmogenic records in Efremovka and derive its exposure age, pre-atmospheric radius and the neutron fluence experienced by it during its cosmic ray exposure duration. The last parameter is particularly important to check whether the ^{36}Cl and ^{41}Ca records found in this meteorite indicate presence of these short-lived now-extinct nuclides in the early solar system or they were produced by cosmic ray secondary neutrons via (n,γ) reactions on ^{40}Ca and ^{35}Cl, during the recent cosmic ray exposure of this meteorite.

We have studied cosmic ray produced noble gas, radionuclide and nuclear track records in this meteorite in detail. A cosmic ray exposure duration of 11.4±1.7Ma and a preatmospheric radius of ~20cm are deduced from the track and noble gas data. Saturation activities of ^{10}Be, ^{26}Al and ^{36}Cl are similar to chondritic values and consistent with the deduced size and a simple cosmic ray exposure of the Efremovka meteorite in interplanetary space. The measured ^{36}Cl activity of 11.5 dpm/kg can at best have ~20% contribution from *in situ* neutron produced ^{36}Cl and suggest that the neutron fluence experienced by Efremovka

is ~10^{14} cm^{-2}. Our data also show that the amount of neutron-produced ^{41}Ca could not account for more than a few percent of the inferred amount based on ^{41}K excess found in this meteorite. Thus, we can rule out effective production of ^{36}Cl and ^{41}Ca in this meteorite by cosmic ray secondary neutrons, which testify to the presence of these short-lived nuclides in the early solar system.

This work was carried out in collaboration with Lawrence Berkeley Laboratory, Univ. of California, Berkeley, U.S.A.

(J.N.Goswami, S.V.S.Murty)

In-situ Measurement of Iodine by Ion Microprobe and Laser-Probe Mass Spectrometry

The potential use of the ^{129}I-^{129}Xe dating system in meteorite and early solar system chronology is hampered by several factors that include a lack of knowledge of the carrier of iodine in meteorites. Phosphates, sulfides and an yet unidentified "minor" phase with high thermal stability are suggested as possible carrier of iodine in ordinary chondrites. The present study is aimed at *in situ* measurement of iodine content in silicate and sulfide phases within individual chondrules of the Semarkona meteorite to identify plausible carrier of iodine and their relative importance.

Polished sections of two chondrules from Semarkona **(Fig. 5.8)**, bulk aliquots of which were analysed earlier for I- Xe systematics using instrumental neutron activation analysis, were chosen for the present study. Ion microprobe data suggest that iodine contents in the silicate phase vary from close to the detection level of ~20 ppb (olivines) to ~140 ppb (pyroxene and glass), whereas the data for sulfide phases yielded values of ~1 ppm. Silicate glass of known iodine contnt (0.1%) was used as a standard and in the absence of a sulfide standard, it was assumed that the secondary iodine ion yields for silicate and sulfide are similar.

The polished sections of the chondrule fragments were removed from epoxy and pressed into high purity Pb foil for laser probe mass-spectrometric studies. We have sputtered selected areas (~100μm x 100μm) of sulfide and silicate phases that were previously analysed by the ion microprobe using a 10μm diameter laser beam in raster mode. The released gas was extracted and intensity of all the xenon isotopes were measured using a pulse counting system. Clear signal of excess ^{129}Xe from ^{129}I decay and of excess ^{128}Xe from (n,γ) reactions on ^{127}I could be seen in the Xe isotopic data for both the silicate and sulfide phases. The iodine content of the sulfide and silicate phases were obtained from the excess ^{128}Xe signal and the sample mass excavated during laser ablation. The iodine content determined for silicate (pyroxene) phase agreed with the ion microprobe results, while the iodine content for sulfides are down by a factor of ~3 than the ion microprobe data. This most probably reflects a higher secondary ion yield of iodine from sulfide phases compared to silicates during ion probe analysis. This work was carried out in collaboration with Wahsington University, St. Louis and Univ. of Arizona, Tucson, U.S.A.

(S.Sahijpal and J.N.Goswami)

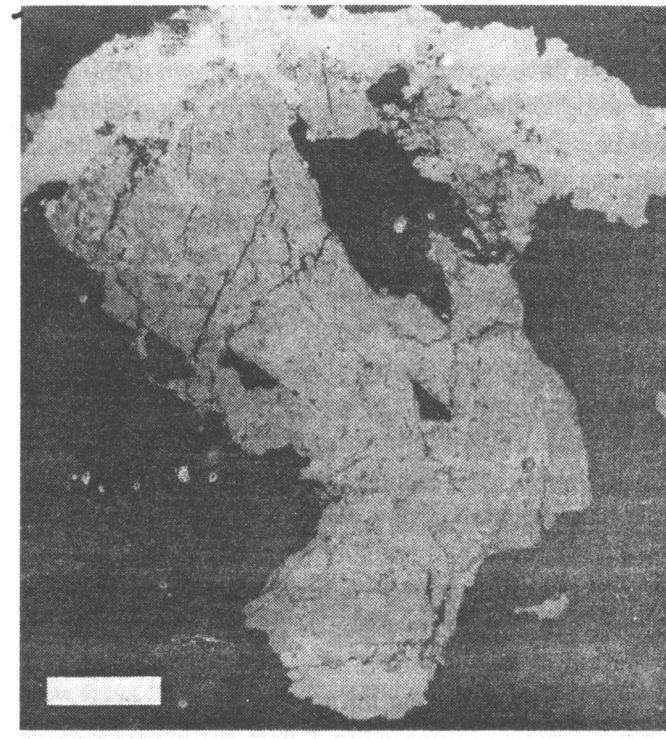

Fig. 5.8 : Scanning Electron photomicrograph of polished section of a broken fragment of a Semarkona chondrule. The brighter (white) areas represent FeS, and the lighter (grey) areas are silicates. Scale bar is 200 μm.

Ar-Ar Geochronology of Deccan Dykes

We have continued our studies related to the geochronology of the Deccan volcanic province, the focus this year being the dykes which may have fed the lava flows. The chronology of the dyke swarms within the Deccan province in particular, and the Peninsular India in general, will help not only in constraining the timing and duration of the volcanism - the prime aim of our study - but will also help us understand the tectonothermal history of the Indian subcontinent around that time. The ages of the dykes range from 67.7±0.8Ma to 61.9±1.0 Ma, consistent with the ages obtained from the lava flows of the province. In an attempt to reconcile the Ar-Ar age data with paleomagnetostratigraphy we dated lava flows which show transition from reversed (R) to normal (N) polarity and obtained ages of 66.7±0.6 and 69.7±0.6 Ma indicating that this R to N transition must be older than 29R having an assigned age of 65.2Ma.. We have summarized the available Ar-Ar ages for the Deccan province published by various groups in **Fig. 5.9** to show that the major pulse of the Deccan volcanism predates the K/T boundary and the 29R chron.

(T.R.Venkatesan, K.Pande and Rashmi Jadeja)

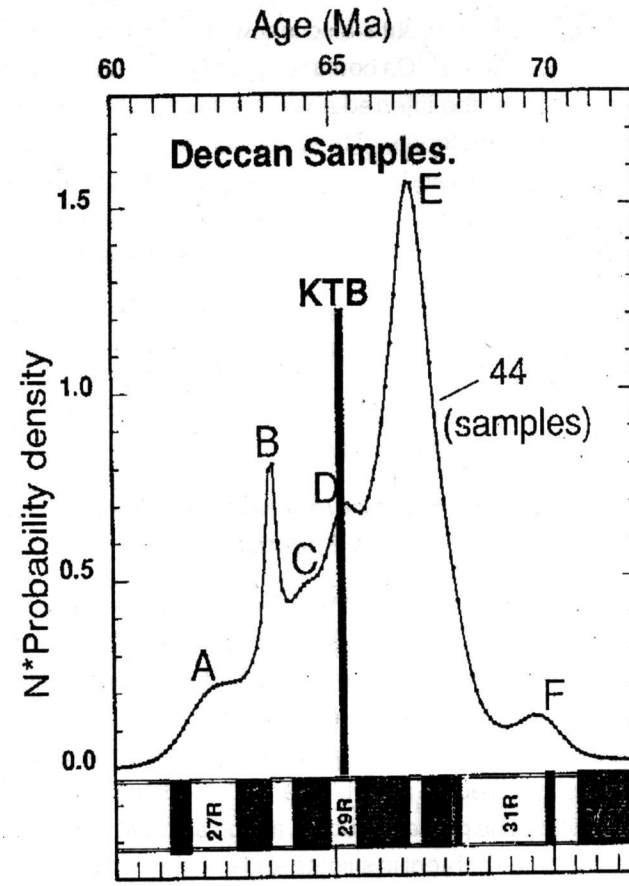

Fig. 5.9 : Probability density distribution for the available $^{40}Ar/^{39}Ar$ ages of the Deccan Province. A,B,C,D,E and F correspond to 3,4,6,5,24 and 2 data points. KTB represents the Cretaceous-Tertiary Boundary. Also shown is a generalized magneto-stratigraphy with the KTB coinciding with 29R chron. Majority of the ages correspond to the point E which is coinciding with the 30R chron (?) and pre-date the KTB.

Nitrogen and Noble Gases in Mantle Xenoliths

We have initiated a new programme to characterize the isotopic composition of nitrogen in various terrestrial reservoirs in an effort to understand the N inventory of the Earth. Information on the nitrogen isotopic composition of the earth's mantle, a major reservoir of nitrogen, is very important in this regard. A combined study of nitrogen and noble gases in samples of ultramafic xenoliths has been carried out to characterize the mantle nitrogen. These xenoliths crystallize at great depths and often contain fluid inclusions with trapped gases and are likely to provide a "clean" sample for the study of mantle gases.

Xenoliths from San Carlos, Arizona

Ultramatic xenoliths at San Carlos make up ~50% of the lower flows in a Quaternary basanite flow. Earlier geochemical studies imply their origin in the subcontinental mantle as partial melting residues at depths of ~70 km. About several hundred milligram quantities of clean mineral separates (olivine and clinopyroxene) have been studied by stepwise extraction for nitrogen and noble gases using mass spectrometric technique.

In the olivine and one of the clinopyroxenes (CP1) separates the gas amounts are too low for precise isotopic studies. In contrast, the second clinopyroxene (CP2) sample, prepared by gentle cleaning, had large gas amounts and the isotopic ratios could be precisely determined. The isotopic ratios of Ne, Ar and Xe in this sample represent a superposition of a mass fractionation effect over mantle composition. This is very clearly seen in the

isotopic composition of Kr for which the mantle composition is same as the earth's atmosphere. Thus, the observed shifts in Kr composition from atmospheric value can be attributed solely to fractionation effect, except at ^{86}Kr, where a fission component is expected. The measured Kr isotope data clearly indicate a linear mass fractionation effect on Kr isotopes favouring the light isotopes. The measured values of $^{20}Ne/^{22}Ne=13.3\pm0.1$, $^{21}Ne/^{22}Ne=0.043\pm0.001$, $^{40}Ar/^{36}Ar=14548\pm153$, $^{129}Xe/^{132}Xe=1.066\pm.007$, $^{134}Xe/^{132}Xe=0.4293\pm0.0022$ and $^{136}Xe/^{132}Xe=0.383\pm0.003$ are also consistent with a mantle component with mass fractionation effect superimposed on it.

Mantle Xenoliths from Kutch and Reunion

The movement of the Indian plate over the Reunion hotspot has been suggested as the principal cause of the Deccan basalt eruption. Studies of mantle xenoliths from Kutch and Reunion have been carried out to study mantle gases and to trace the composition of the mantle source from Kutch to Reunion. Due to scarce amount of gas, only N, Ne and Ar could be analyzed for isotopic systematics. There is a distinct difference between the Kutch xenoliths and Reunion dunite in their isotopic patterns. Higher ^{21}Ne and ^{40}Ar in the Kutch xenoliths, as compared to Reunion dunite, cannot be generated *in situ* during 65 Ma (age of Kutch xenoliths) and hence reflect a source signature. The Ne isotopic data shown in **Fig. 5.10** suggest that the data fall along the mixing line joining 'air' and 'MORB' compositions. Though the Reunion data is consistent with air composition, the lower amount of ^{36}Ar, as well as higher $^{40}Ar/^{36}Ar$ ratio, rule out air contamination. The most likely explanation of these differences is the presence of a lower mantle component in Reunion dunite, having air like $^{20}Ne/^{22}Ne$ but $^{40}Ar/^{36}Ar$ >4000.

The $\delta^{15}N$ in both San Carlos and Kutch xenoliths indicates a two component mixture. A lighter low temperature component and a heavier high temperature component are evident; the low temperature component most probably reflecting the component from the fluid inclusions. Vacuum crushing experiments are in progress to further check this possibility.

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

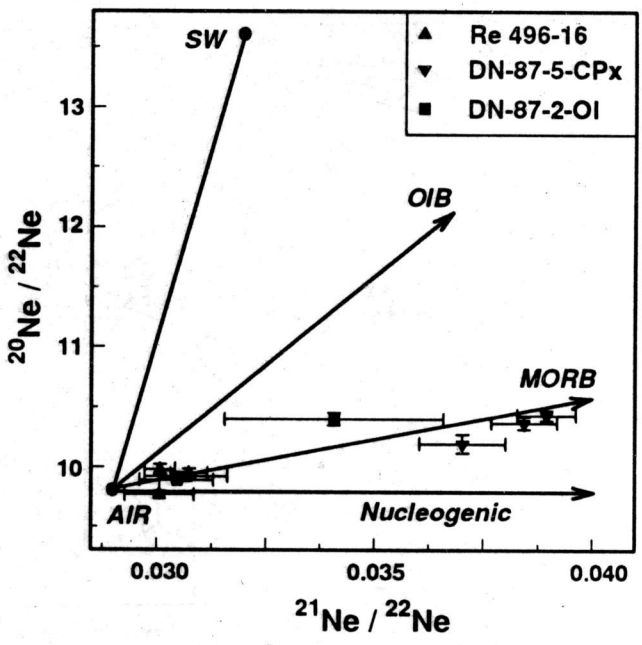

Fig. 5.10 : Neon three isotope plot for the stepwise heating data of Mantle xenoliths from Reunion and Kutch.

Geochronological Evolution of the Singhbhum Craton : An Ion Microprobe Study

The Singhbhum-Orissa Iron Ore Craton of eastern India is a triangular crustal block of Precambrian age covering an area of about 40,000 km^2. The province contains an almost continuous geological record from the Archaean to the Mid-Proterozoic. The oldest rocks of sedimentary origin recognized in this craton are designated as the Older Metamorphic Group (OMG). The type area of the OMG is around Champua (**Fig. 5.11**) where it is intruded by biotite-hornblende tonalite and granodiorite gneisses designated as the Older Metamorphic Tonalite Gneisses (OMTG). This was followed by the emplacement of the voluminous Singhbhum Granite (SBG) and the formation of the Iron Ore Group of rocks. These pahses of activity were followed by a pause in crustal growth that was interrupted by a sedimentary and a volcano-sedimentary cycle. One of the last phases of acid plutonism in this craton is represented by the Mayurbhanj Granite (MBG) whose emplacement marked the stabilization of the crust in this region. Although several attempts have been made earlier to obtain a geochronological

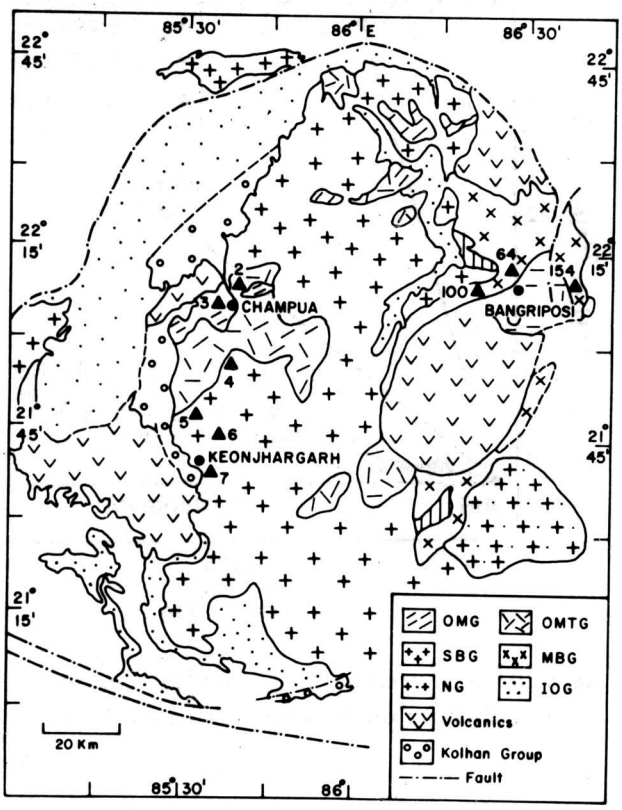

Fig. 5.11 : A geological map of the Singhbhum Craton in eastern India. The various litho-units are : OMG (Older Metamorphic Group), OMTG (Older Metamorphic Tonalite Gneisses), SBG (Singhbhum Granite), MBG (Mayurbhanj Granite), IOG (Iron-Ore Group) and NG (Nilgiri Granite). The filled triangles indicate sample locations.

framework for this important crustal block, most of them are based on K-Ar, Ar-Ar and Rb-Sr systematics that are often disturbed and precise information on the formation age of some of the major lithounits (OMG, OMTG and MBG) is stil lacking. We have undertaken a detailed $^{207}Pb/^{206}Pb$ dating of single zircon of these litho units to obtain their precise formation ages. Our data suggest that the oldest crustal component present in the Singhbhum Craton had an age of ~3.6 Ga as reflected by the ages of detrital zircons found in OMG group of rocks. The formation of OMTG took place at ~3.4 Ga, while the time difference between the emplacement of Singhbhum Granite (zircon age ~3.3 Ga) and OMTG group appear to be much shorter than previously assumed. The ~3.1 Ga age for Mayurbhanj Granite, is much higher than reported ages of ~2.1 Ga from Rb-Sr data. Our results suggest a rapid evolutionary sequence for the Singhbhum Craton that got stabilized at ~3.1 Ga, much earlier than the stabilization age of 2.5 Ga for the Aravalli Craton, another prominent Archean craton within the Indian subcontinent, which we have studied earlier.

(S.Mishra, M.P.Deomurari, N.Sinha and J.N.Goswami)

Evidence for Cometary Impact at the K/T Boundary

We have identified an intertrappean bed in the Anjar volcano-sedimentary sequence in Kutch which encompasses the K/T boundary. Preliminary studies of this section reported last year show at least three thin horizons which are rich in iridium, osmium and other diagnostic elements. Detailed geochemical studies of the sequence are now completed. The data confirm the earlier findings and also suggest that the three distinct layers have been deposited at time intervals of a few thousand years. The horizons are patchy but traceable throughout the sequence. Multiplicity of such horizons are indicative of multiple impacts and the data support cometary instead of asteroidal impact. A model in which the comet breaks up in to many nuclei in circum-solar orbit which are eventually intercepted by the earth has been proposed. Further studies to identify the nature of the bolides, post impact processes and its relation to biological extinction is being carried out.

(N.Bhandari, P.N.Shukla, S.Kusumgar, K.Pande, K.M.Suthar and T.R.Venkatesan)

Cosmogenic Nuclides in Terrestrial Samples as Traces for Geomorphological Studies.

We have explored several new applications of cosmogenic radionuclides in terrestrial settings, which became possible with the availability of the high sensitivity atom counting method (AMS : accelerator mass spectrometry) for long-lived cosmogenic radionuclides ^{14}C, ^{10}Be, ^{26}Al and ^{36}Cl. On the earth there are two modes of production of these radionuclides: production as a result of cosmic ray interactions with (i) atmospheric nuclei, and (ii) nuclei present in materials on the surface

of the earth. The cosmic ray intensity is appreciably reduced at atmospheric pressures 600 $g.cm^{-2}$, whereby the in-situ cosmogenic nuclides in terrestrial materials can be studied only using the AMS. But several of the atmospheric nuclides which could be studied earlier using the decay particle counting method, can now be studied more conveniently using the AMS method, permitting studying time-series in proxy records, e.g. marine sediments and in ice sheets.

We developed convenient methods for studying in-situ ^{10}Be and ^{26}Al in quartz present in terrestrial rocks, and also for in-situ ^{14}C in terrestrial samples, which is a hard task because of the ubiquitous atmospheric ^{14}C. By measuring cosmogenic ^{10}Be, ^{26}Al and ^{14}C, we have now shown convincingly and repeatedly that several of the in-situ cosmogenic nuclides can be used for studying several outstanding problems in geomorphology. These studies were carried out in collaboration with Drs. J.R. Arnold and K. Nishiizumi of the Univ. of California, San Diego; J. Klein and R. Middleton of the Univ. of Pennsylvania; M. Caffee and R.C. Finkel of Lawrence Livermore National Laboratory; and A.J.T. Jull and D.J. Donahue of the Univ. of Arizona at Tucson.

In two other experiments concluded successfully, we have used atmospheric ^{10}Be as a tracer for studying (i) the ages and rates of soil formation, and (ii) the climatic variations and weathering histories of loess deposits in the Chinese Loess Plateau, back to about 5 my. In another study, we have successfully shown that soil erosion rates can now be determined using in-situ cosmogenic radionuclides, ^{14}C and ^{10}Be.

(D. Lal)

Energetic ^{14}C Atoms in Interplanetary Space

From studies of surficial and deep-seated lunar soil and rock samples, we have been able to confirm an earlier hypothesis that there exists a source of energetic ^{14}C atoms in interplanetary plasma, which are surface-implanted on moon. It is tentatively concluded that the ^{14}C atoms are presumably of solar origin (presumably of nuclear origin in the solar photosphere) and are carried with the solar wind which is freely implanted on the lunar surface. This work was caried out in collaboration with A.J.T. Jull and D.J. Donahue of the Univ. of Arizona at Tucson.

(D.Lal)

Facilities

at

PRL

COMPUTER CENTRE

The usage of IBM work-stations (IBM Rs 6000/580) and HP 9000/735 installed at Computer Centre has picked up during the current year. The users are extensively using powerful mathematical and scientific packages through Campus-wide local-area network running twenty four hours a day.

The other facilities available are global E-mail, Telnet, FTP and WWW through VSAT. The VAST (very Small Aperature Terminal) was installed during the year which provides us Internet Connectivity through the hub at Bangalore.

We have installed new version of AIX-OS during the year. Also, latest version of MATHAMETICA, IMSL-Exponent Graphics, IDL were installed during the year to provide solution to some of the major software issues.

The other activities of the Centre include consultation to the users, teaching to the research scholars, taking care of Ethernet and Internet connectivity, helping users in all respect.

LIBRARY

Collection

The PRL Library subscribes 201 scientific and technical Journals. A large number of Scientific Reports, Data, Maps, etc. are also received. 204 books were added to the Library.

Services

Over 1,15,000 photocopies were made according to requests received from PRL personnel, from other Libraries and Research scholars outside PRL. Requests were received for obtaining 380 publications from other Libraries and Research scholars outside PRL.

Requests were received for obtaining 380 publications from other libraries on Inter-Library-Loan. Most of these publications were obtained on loan for our readers. About 200 publications were loaned by us to other libraries.

During the year, 5706 books and journals were issued. Several queries were received for providing factual information, locating addresses, giving biodata, preparing bibliographies etc.

Accessing Electronic Resources

A large number of Electronic Resources such as Listservers or Discussion Group, OPACs (online Public Access Catalogues), Newsgroups, Databases, Reference Tools and Journals are available on the Internet. There are over a hundred full text, peer reviewed science technical and medical journals on the Internet.

Since many resources are at present available free of cost, the library has identified the URLs ie the Uniform Resource Locator of all the Journals, both subscribed and also not subscribed but which are of interest to our readers.

URLs of Reference Sources and also Servers in Physics, Astronomy & Earth Science have been traced. These Internet resources have been used to answer several reference queries.

ELECTRONICS LABORATORY

Electronics laboratory is engaged in the development of embedded applications using state of the art microprocessors, microcontrollers and digital signal processors and Fuzzy devices.

The development environment consists of necessary hardware and software tools for a series of microcontrollers of 8 and 16 bit namely 8051 and 8096 series, ADSP2100 and TMS32025 digital signal processors and a Fuzzy logic development system.Other facilities consists of PCs, workstation, multimedia systems and ECAD tools.

The work carried out in microcontroller area is implementation of distributed and shared memory architecture suitable for implementing neural network algorithms. The built in analog and digital I/O of microcontrollers provide the frontend interface for the application. The implementation of pattern recognition with fuzzy comparator is in progress.

The application of neural network for human like problem solving is being carried out through simulation as well as implementation on a Robot. A simulation of the human walk using neural networks has been developed. A pioneer robot is being used for neural network algorithm testing.

Electronics Lab has contributed to a great extent in building and maintaining the PRL campus LAN. The network is based on FDDI/ethernat technology and uses TCP/IP protocol for communication. The physical LAN consists of thick backbone and about 40 thin segment providing connectivity to more than 150 PCs at present. The LAN nodes can access internet through various client software and IBM RS600 work stations. Trainee students are encouraged to develope client/server applications using TCP/IP protocols.

For detailed work on neural network refer to p.51 under Theoretical Physics Chapter.

About 30 students from engineering colleges undertook their project work in Electronics Laboratory. They completed their projects successfully.

WORKSHOP

With the existing facilities of workshop like general purpose machine shop, drawing section, welding section & painting section, the workshop has played an important role in designing, developing and manufacturing of various systems for scientific experimental group.

Some of the important major jobs done during the last year are listed below:

For planetary atmosphere and aeronomy division, the L. P. Sensor Probe for rocket RH 560 was designed, developed and fabricated. This probe was used to measure electron density from upper atmosphere. This job was assembled with 12 critical components made up of s.s and brass material in the order of accuracy 5 microns.

Hand held photometer was designed and fabricated within the tolerances.

For basic physics laboratory, an experimental device was designed and fabricated to study experimentally the charging of dust particles, their confinement against gravity and transport mechanism in the flowing plasma. This system include for leak proof s.s.304 chamber of dia. 270 mm. which is evacuated to 10^{-6} m-bar. A precised plasma gun made from s.s. and a duster in pulse mode for dust injection in the plasma.

For planetary atmosphere and aeronomy division, the precised components from aluminium, s.s. and brass material were made with specified tolerances and assembled for few systems which were installed with the fabricated stand at Aeronomy Observatory at Mt. Abu. They are (a) Day-glow photometer, (b) Multi Wavelength Daytime photometer, (c) Night time Fabri-Perot spectrometer and (d) Day-time sodium spectrometer.

A sophisticated 12 v. D.C. motor operated mechanical drive arrangement in two stage reduction was designed and fabricated. This system is used to accomplish the rotational motion to get six shots per second and translational motion of fine movement of metallic target to be used in the Laser Produced Plasma Experiment. This system includes shaft of dia. 10 mm and 360 mm long made from s.s.304 having on one end fine pitch of 1 mm thread and a surface finish of 10 microns.

An inner electrode of s.s.304 material was made for photometer. This job was made in one piece of s.s.304 material of dia 47.7 mm. This job includes an accurate operation of inner and outer tapper turning with specified angle. It also includes an operation of accurate turning of the order 5 microns and a surface finish of 16 microns to achieve a uniform wall thickness of 0.85 mm.

It also includes, three slit cutting of the size of 2.5 mm width at 120 $^{\circ}$ apart on external tapper surface. This operation was done on milling machine with an accuracy of 10 microns.

Over and above the general routine work, the repairing and modification of various systems and machines ; fabrication of structural work ; high vacuum welding joints and the repairing vacuum pump were successfully were carried out.

The workshop at Thaltej enjoyed a very busy schedule. An Interferometer and many other optical instruments needed for on observing total Solar Eclipse were developed. Precision machining up to 0.001" and angular accuracy of 1 arc minute was achieved in assembly work. All the instruments had worked well.

Reduction drive for Spectrometer, Dewar and Twin Dewar mounting plate, several X - Y movement, mirror mount and chopper plate were made with fine dimensional accuracy up to second decimal fraction of millimeter.

Cassegrain plate with heavy duty mount is made for the testing facility of all the instruments developed for IR Telescope. 7 filter holder drive unit was fabricated for CCD mount. Dimensional accuracy and precision assembly work was involved. Very often our staff visited Mt. Abu for assisting scientists in observation work as well as in carrying out maintenance work.

ENGINEERING SERVICES

The Engineering services render all technical services pertaining to civil engineering works and related building and laboratory services such as air-conditioning, electrical, elevators, inter communication system, public acquisition to maintenance and upkeepment of all buildings and campuses (residential and non-residential and its related technical services). The functions of Civil Engineering and Engineering Maintenance Division architectural planning, designing, estimating and execution of various services, landscaping horticultural development and maintenance and upkeepment, interiors and furnishings of buildings and structures of all the campuses - PRL Main campus, Colony Campus, Thaltej Campus. Mt. Abu Campus and Udaipur Campus. Site preparation works for installation of sophisticated research equipments by meeting with their clean room specifications and other special requirements are also executed.

During the year, following works have been undertaken.

- Development of Abu Campus
- Partition works in USO new building
- Extension of PRL Guest House - in progress
- Site preparation for Laser Physics Laboratory

Honorary Fellows

at PRL

Professor Hannes Alfvén

Professor J.E. Blamont

Professor S. Chandrasekhar

Acad. V.L. Ginzburg

Professor B. Rossi

Professor J.B. French

Professor A.M.J. Tom Gehrels

Professor D. Lal

Professor P.R. Pisharoty

Professor M.G.K. Menon

Professor S. Dhawan

Professor U.R. Rao

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 J C Parikh FNASc	Particle Physics	Ph D Chicago Univ. (1962)
Prof B L K Somayajulu FNA, FASc, FNASc	Geochemistry and Oceanography	Ph D TIFR Bombay Univ.(1970)
Prof N Bhandari FASc, FNASc	Planetary Physics	Ph D TIFR Bombay Univ. (1967)
Prof J N Desai FNASc	Expt. High Resolution Spectroscopy, and Light Scattering	Ph D Gujarat College, Gujarat Univ. (1964)
Prof A C Das	Theoretical Plasma Physics, Space Plasmas	Ph D Imperial College London Univ. (1968)
Prof S B Khadkikar	Particle Physics	Ph D TIFR, Bombay Univ. (1970)
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)
Dr A Bhatnagar FNA	Solar Physics	Ph D Agra Univ.(1965)
Dr V B Sheorey	Theoretical Atomic Physics and Non linear Dynamics	Ph D Univ. College, London Univ.(1968)
Dr A S Joshipura FASc	Particle Physics	Ph D Bombay Univ. (1979)
Dr S D Rindani	Particle Physics	Ph D IIT, Bombay (1976)

Name	Specialisation	Academic Qualification
Dr A K Singhvi	Palaeoclimatology and Geochronology	Ph D IIT, Kharagpur (1975)
Dr D K Chakrabarty	Ion and Neutral Chemistry of Earth's Atmsophere	Ph D NPL, Delhi Univ. (1973)
Dr Harish Chandra	Ionospheric Studies and Dynamics of Middle Atmosphere	Ph D PRL, Gujarat Univ. (1970)
Dr S K Bhattacharya FASc	Isotope Geochemistry	Ph D PRL, Gujarat Univ. (1980)
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)
Dr R Sridharan FASc	Upper Atmospheric and Ionospheric Physics	Ph D PRL, Gujarat Univ. (1984)
Dr P Sharma	Geophysics and Hydrology	Ph D PRL, Gujarat Univ. (1977)
Dr U C Joshi	Star Formation, AGNS and Comets	Ph D Kumaun Univ. (1981)
Dr P N Shukla	Geochemistry	Ph D IIT, Kanpur (1977)
Dr N M Ashok	Infrared Observations	Ph D PRL, Gujarat Univ. (1983)
Dr T Chandrasekhar	Optical & Infrared Astronomy	Ph D GujaratUniv. (1982)
Dr B R Sitaram	Classical Mechanics, Mathematical Physics, Computer Simulations	Ph D Delhi 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 H S S Sinha	Upper Atmospheric and Ionospheric Studies	Ph D PRL, Gujarat Univ. (1977)
Dr A Jayaraman	Atmospheric Aerosols and Radiative Studies	Ph D PRL, Gujarat Univ. (1985)

Name	Specialisation	Academic Qualification
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 Utpal G Sarkar	Particle Physics	Ph.D CalcuttaUniv. (1984)
Dr A K Ambastha	Solar Plasma Physics	Ph D PRL, Gujarat Univ. (1981)
Dr J Banerjee	Laser Physics	Ph D ,City Univ.(NY)(1982)
Dr G Subramaniam	Cosmic Ray Physics	Ph D PRL, Gujarat Univ. (1965)
Dr Sushil Kumar Gupta	Geophysics, Hydrology	Ph D IIT, Bombay (1974)
Dr R K Pant	Geomorphology	Ph D Banaras Univ. (1977)
Dr V N Nijampurkar	Glaciology	Ph D TIFR, Bombay Univ. (1977)
Dr D R Kulkarni	Computational Physics	Ph D M S Univ (1972)
Dr (Mrs) S R Rao	Mathematical Statistics	Ph D Univ. of Ottawa(1963)
Dr A M Punithavelu	Experimental Plasma Physics	Ph D Patrice Lumumba Univ., Moscow (1975)
Dr (Miss) S L Kusumgar	Palaeoclimatology, Chronology	Ph D PRL, Bombay Univ. (1980)
Dr G D Vyas	Upper Atmospheric and Ionospheric Studies	Ph D PRL, Gujarat Univ. (1980)
Dr Sai K Iyer	Large Scale Structure, General Relativity	Ph D Washington Univ. USA (1987)
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 Kanchan Pande	Geology, Geochronology	Ph D PRL, Gujarat Univ. (1990)
Dr Syed Aftab Haider	Planetary and Cometary Atmospheres	Ph D Banaras Univ. (1984)
Dr P Janardhan	Radio Astrophysics	Ph D PRL, Gujarat Univ. (1992)
Dr R Sekar	Upper Atmospheric and Ionospheric Physics	Ph D PRL, Gujarat Univ. (1991)

Name	Specialisation	Academic Qualification
Dr J R Trivedi	Geochronology	Ph D PRL, Gujarat Univ. (1991)
Dr Subhendra Mohanty	Astroparticle Physics	Ph D Wisconsin Univ. (1989)
Dr Debi Prasad	Solar Cometary Physics	Ph D PRL, Gujarat Univ. (1990)
Dr S C Tripathy	Solar Physics	Ph D PRL Gujarat Univ. (1993)
Dr Ashok K Singhal	Radio Astronomy	Ph D TIFR Bombay Univ. (1993)
Dr Rajmal Jain	Solar Physics	Ph D PRL Gujarat Univ. (1983)
Dr J R Bhatt	Astrophysics	Ph D Gujarat Univ. (1992)