वार्षिक रिपोर्ट
1996-97
Annual Report

भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद

Physical Research Laboratory
Ahmedabad

Important Visitors at PRL

Sydney Chapman

S. Chandrasekhar
Oct 2 - 16

C. V. Raman
26.12.1953

Norbert Wiener " " "

Morarji Desai
10/4/54

Vijaya Lakshmi Pandit.
10.4.54.

Indira Gandhi

इंदिरा गांधी

Jawaharlal Nehru
10.4.1954

30.10.73

Feb 18, 1997

To day I had the opportunity of attending the Golden Jubilee celebration of Physical Research Laboratory. The service rendered by this Institute for the progress of the country in Space Technology is unique. The [illegible] and vision, Dream of late Vikram Sarabhai who is the architect of this Institute is fulfilled by ~~the~~ his successors (Scientists) and today this laboratory has acquired international reputation in the space technology. My good wishes all the scientists who have contributed their service in this laboratory

H D Deve Gowda

भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद
PHYSICAL RESEARCH LABORATORY
Ahmedabad

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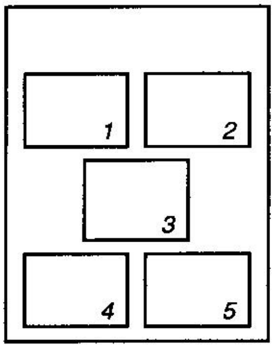

Glimpses of Prime Minister Shri H. D. Deve Gowda's visit to PRL on February 18, 1997 for the Golden Jubilee Celebrations.

1. *Shri H.D. Deve Gowda, with Gujarat Governor Shri Krishna Pal Singh and Chief Minister Shri Shankarsinh Vaghela.*
2. *Inauguration of the Golden Jubilee Celebrations.*
3. *Release of the Golden Jubilee Brochure,* ***Fifty Years of PRL*** *by Shri H.D. Deve Gowda.*
4. *Inauguration of the PRL Open House Exhibition.*
5. *Prof. U.R. Rao explaining an exhibit on Udaipur Solar Observatory to the honourable guests.*

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Prof. G.S. Agarwal (Ex-Officio)	Director Physical Research Laboratory

Secretary

Dr. Dinesh Patel (Ex-Officio)	Registrar / Head, TS Physical Research Laboratory

Contents

Introduction

The year 1996-97 has been a momentous period for the Physical Research Laboratory. On November 11, 1996 the laboratory entered its fiftieth year of existence. Founded in 1947, by Dr. Sarabhai at the humble surroundings of M.G. Science Institute, the laboratory has advanced leaps and bounds over the five decades. This is also the year in which the Department of Space in whose formation and nurturing the laboratory has played significant role is completing its twenty fifth year. During the past fifty years the laboratory's strength and its scientific activities have grown tremendously. Today, PRL has developed into a big campus of its own, with several buildings, laboratories and facilities at Ahmedabad, an Astronomy Centre at Thaltej, a Solar Observatory at Udaipur and an Infrared Obervatory at Mt. Abu. The science at PRL has grown significantly and currently covers a wide spectrum in the various areas of astronomy and astrophysics, planetary and space sciences, earth sciences, theoretical physics and laser and quantum optics.

The year 1996-97 was also the year for astronomers. The appearance of two bright comets the Comet Hyakutake (C 1996/B2) and Comet Hale-Bopp kept them busy. Apart from conducting photopolarimetric studies of these comets and widefield photography and near infrared observations, a few public viewing and popular lectures were carried out.

The laboratory has also started a new initiative in the area of computer sciences. A collaborative program on image processing and pattern recognition is being worked out jointly by Space Applications Centre, Ahmedabad and PRL Computer Science group. In addition, the laboratory is participating in international collaboration like INDOEX, ISRO-DFVLR rocket campaigns, UNESCO sponsored International Geological Correlation Programmes on Deserts and Palaeomonsoon and Trace Gas Studies in GOA with CSIRO, Australia. The laboratory participated in an International Oceanographic Cruise in the South-Western Atlantic Ocean on-board RV KNORR as a part of the Contaminant Baseline Survey, an activity sponsored by the International Oceanographic Committee.

The laboratory's contribution to basic research in various fields has been recognised both nationally and internationally. Some of our scientists have been honoured by a number of prestigious national and international honours and awards such as the prestigious Vikram Sarabhai Award by the 31st COSPAR Scientific Assembly at Birmingham, UK and the Geochemical Society's V. M. Goldschmidt Medal, USA and fellowships to various scientific academies such as the Third World Academy of Sciences, ICTP, Italy. The laboratory continued to contribute significantly in national and international scientific scene with its large number of first rate publications. A total of one hundred and ten papers have been published, of which eighty seven were in high impact journals. During the year our scientists have convened five symposia/ workshops, two of which were organised during the 31st COSPAR Scientific Assembly held at Birmingham, UK. Also our scientists continued to participate actively in national and international conferences with large number of invited and contributed presentations. During the reporting year about one hundred and seventy two papers were presented out of which seventy one were invited review talks and about fifty eight were presented in international conferences.

The Golden Jubilee Year Celebration of the Laboratory began on November 21, 1996. Prof. U.R. Rao, Chairman, PRL Council of Management inaugurated the function at the K. R. Ramanathan auditorium. Mrs. Mrinalini Sarabhai alongwith Directors of different institutes at Ahmedabad attended the function. Many of our retired personnels and members of PRL alumni joined us on this day. To mark the beginning of the fiftieth year all staff members, including the retired personnel, were presented a gold plated memento. A video entitled *PRL- 50* was released by Prof. Rao.

The Golden Jubilee Celebrations were enriched with a visit by the Hon'ble Prime Minister Shri H.D. Deve Gowda to PRL on February 18, 1997. During his visit Shri Deve Gowda released the Golden Jubilee Brochure *PRL at 50* and inaugurated the Open House Exhibition. The Open House Exhibition was kept open for schools, colleges and general public from February 19 - 22, 1997. About thirty thousand school children from different districts of Ahmedabad, Gandhinagar, Vadodra, Bulsar, Mehsana, Kutch and Saurashtra visited the exhibition. In addition the general public also took the opportunity to acquaint themselves with PRL and its activities. The salient features of the open house were scientific exhibits, live demonstrations, science films on video, computer displays and night viewing of the sky through telescopes.

Prof. W. E. Lamb, **Nobel Laureate** visited the laboratory as Vikram Sarabhai Professor. Prof. U. R. Rao and Prof. C. N. R. Rao delivered the ninth and the tenth Prof. K. R. Ramanathan Memorial Lectures. The laboratory organised a series of public lectures by distinguished invitees covering a wide spectrum of topics. The topics varied from Magnetic Resonance Imaging of Human Lung by Prof. M. Leduc, Large Depletion of Atmospheric Ozone Due to CFCs by Prof. Paul Crutzen, **Nobel Laureate** to Astronomy at the Turn of a Millenium by Prof. P. Lena.

As a part of our effort to interact with the teaching community and the student community in Ahmedabad and in Gujarat region, PRL organised a refresher course for college teachers from May 27 to June 14, 1996. Response for participation from college teachers was very enthusiastic. Sixty three teachers attended the course. The course consisted of lectures on various topics in Physics, general lectures on topics of current interest, visits to various laboratories in PRL and Institute for Plasma Research (IPR), and demonstration of computer software for teaching physics. The valedictory function was arranged on 14th June during which certificates were distributed. At the function a large number of participants expressed their satisfaction with the course and hoped that PRL will organise more such courses in future.

As a part of PRL's Golden Jubilee celebration, the first workshop on *Solar Physics in India during the Next Solar Maximum and Beyond* was held at Udaipur Solar Observatory, Udaipur during October 7-10, 1996. The main aim of the workshop was to plan coordinated solar studies using the existing facilities spread over various institutes within the country, and to identify the future requirements for solar research during the next solar maximum and beyond. A wide range of fields were covered by the workshop, including the present and future solar instrumentation, magnetic field measurements, solar flares and transients, solar wind and interplanetary medium, solar and heliospheric plasma physics, solar eclipse, helioseismology and collaboration projects like GONG, YOHKOH and SUMER.

A workshop on *Perspectives in Atmospheric Chemistry* was organized at PRL during December 26 - 27, 1996. Prof. P. Crutzen gave the key note address. There were twenty detailed presentations on tropospheric and stratospheric chemistry, climate, greenhouse effect, trace gases, aerosols etc. The panel emphasized the need to study the large biosphere in the tropical regions due to its important role in the global atmospheric chemistry.

The Theoretical Physics Division of PRL organised a five-day meeting on *Gravitation and Particle Physics.* Issues concerning the fundamental interactions at theoretical, phenomenological and observational levels were discussed at length. During the meeting there were three evening lectures by Prof. C. V. Vishveshwara on The Cosmic Picture Book, by Prof. J. C. Parikh on Time Series Analysis and by Prof. S. B. Khadkikar on Confined Colours. The symposium provided an excellent opportunity for researchers in Gravitation Physics and Particle Physics to exchange ideas and focus attention on emerging new fields of astroparticle physics.

With the initiative of Dr. Abhijit Pandya, Associate Professor, Florida Atlantic University, USA a five day course on *Object Oriented Programming and Artificial Neural Network* was organized at PRL from February 24 to 28, 1997. The objective of the course was to introduce the concepts of object oriented programming which is very essential in the development of large and complex software for various disciplines in science and engineering. The participants were from academics, R & D Labs, industry and from PRL including a good number from DOS/ISRO units.

The popularity and the outstanding success of the Golden Jubilee Year Celebrations, especially the Open House and various workshops and symposia was itself a reward for PRL members who had lent whole-hearted support and spent a large amount of time and efforts in organising these activities.

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

GS Agarwal

Director

PRL
in a
Nutshell

Scientific Achievements

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

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

The chart below profiles the scientific activities of the laboratory.

Some of the important research contributions are summarised.

Astronomy and Astrophysics

The research activities of the Astronomy and Astrophysics Division encompass a wide range of topics like the Sun, the interplanetary medium, star formation, stellar evolution, high angular resolution studies, studies of galaxies and active galactic nuclei. Modelling work is also being carried out to explain the observations.

The Astronomy and Astrophysics Division is located in a campus at Thaltej, seven kilometers west of PRL. At Mt.Abu an infrared observatory with a 1.2m telescope and a host of back-end instruments (like photometers and polarimeters in the optical and infrared, CCD camera, infrared camera, Fabry-Perot spectrometers) cater to the observational needs of the astronomers. The observations on Sun are being carried out at Udaipur Solar Observatory (USO). Three solar telescopes are housed in an island observatory in Fatehsagar lake and a GONG experiment in the USO campus to study the solar oscillation modes and to probe the solar interior using helioseismology.

During 1996-97 there was an opportunity to observe two bright comets, Comet Hyakutake (C 1996/B2) and Comet Hale-Bopp. For a decade and half astronomers were craving for bright comets, the desire was fulfilled with the arrival of these two comets. Photopolarimetric studies of these two comets were undertaken to study, in detail, the characteristics of gas and dust. Widefield

Profile of Scientific Activities

- **Basic Sciences**
  - Astrophysics
  - Atomic & Molecular Physics
  - High Energy Physics
  - Infrared & Radio Astronomy
  - Laser Physics and Quantum Optics
  - Nuclear Physics
  - Plasma Physics
  - Solar Physics
  - Non-linear Dynamics
  - Neural Networks
  - Climate Studies
- **Atmospheric Sciences**
  - Upper Atmospheric Studies
  - Middle Atmospheric Studies
  - Laboratory Astrophysics
  - Planetary Atmospheres
- **Earth Sciences & Solar System Studies**
  - Oceanography & Geochemistry
  - Paleoclimate
  - Hydrology
  - Evolution of Solar System Objects
  - Cosmic Ray Prehistory
  - Catastrophic Events in Earth's History
  - Evolution of Indian Lithosphere

photography and near infrared observations were also carried out.

The programme to detect microvariability in polarization, for AGNs was continued. Day to day variations in Mrk 421 have been observed. Modelling work in AGN has been initiated this year. Theoretical synchrotron spectrum was used in conjunction with the observed spectrum to obtain the value of magnetic field in the emission region (0.93 Gauss) and the cooling time (5×10^7 sec) for the quiescent continuum spectrum. Studies have shown that a simple unified scheme model for AGN does not fit the observations. Hence a new model for AGN is to be worked out. Substantial work has been done in the starburst galaxies using the new CCD camera. Fifteen galaxies ranging from the elliptical to spiral galaxies were observed, in which starburst activities have been found in the nuclear and extranuclear regions. Two interesting results are (i) the detection of a distinct ring of star formation around the nucleus of a galaxy Mrk 332 and (ii) a ring around a galaxy Mrk 87.

Kinematic studies on HII regions in Lagoon nebula using an imaging Fabry-Perot Spectrometer show complex structures. Notable expansion of ionised gas and the presence of turbulence has been detected. Similar results have been confirmed by the Hubble Space Telescope observations.

Simultaneous multiwavelength X-rays, UV and Optical monitoring of the variability of the B2e star I Eridani was done as a part of the international collaboration. Possible low level fluctuations in the ROSAT X-ray data occurred at the same time as unusual activity in the spectral lines $H\alpha$, He I, Ne II and CIV as observed in the optical and UV regions.

The lunar occultation observations in near infrared were made to determine angular sizes for six M giants from which effective temperatures of the star were derived. Near infrared photometric studies of Algol type eclipsing binary system RZ Cas were made. The light curves were analysed using Wilson's model to determine the orbital inclination, mass, radius, temperature and luminosity.

Coordinated observations of radio bursts at meterwave radiation were made using Hiraiso radio spectrograph (Japan) and IPS arrays at Rajkot and Thaltej as a part of the international collaboration. The plasma density enhancements were found to be directly correlated with the geomagnetic disturbances on the Earth. Rotational modulation of microwave solar flux was found to consist of (i) localised emission which almost vanishes during the low sunspot years and (ii) a background emission which persists even during low solar activity. The IPS observations were used for the determination of structure and dynamics of the solar wind.

Solar active regions are investigated using He I 10830 A spectroheliograms, YOHKOH soft X-ray images, vector magnetograms etc. The active region NOAA 7978 had three distinct phases of evolution with apparent flux imbalance. Highly sheared magnetic field structure of the active region NOAA 6555 led to a large X-class flare whose site was characterized by a new rising "emerging flux region".

The performance of the telescope was satisfactory. Astronomers at PRL and other institutes extensively used the telescope. This year the telescope drive system was improved. The existing CCD camera was improved and observations were made. The infrared camera was acquired. Work on two channel near infrared fast photometer for lunar occultation studies and an optical fibre-fed grating spectrograph are in progress.

Theoretical Physics

Understanding the inertial forces in the context of general relativity has been an important aspect of study wherein the formalism is applied to define a new characterisation called cumulative drag index that signifies rotation as an intrinsic feature of axisymmetric stationary spacetimes. Further,the application for analysing the ellipticity of slowly rotating collapsing configurations with different equations of state has brought out a novel feature of the configurations getting to be prolate instead of the generally assumed oblate shape. In the studies related to gravitational waves a general formula accurate to $0((v/c)^9)$ for gravitational radiation in binary systems has been derived, which is valid for general orbits and for a class of coordinate gauges. On the other hand,the propagation of gravitational waves in matter has been treated using perturbations of Einstein's equations for a perfect fluid distribution analysed upto second order in perturbation.

Neutrino mass generation through lepton number violation and its consequences both in astrophysical and collider physics contexts has been of considerable interest and several new results have been obtained. It is realised that neutrino mass constraints considerably limit the interpretation of recent HERA data in terms of the production of supersymmetric counterparts of quarks. Further, it has been shown that models suggested for understanding the smallness of neutrino masses can have testable phenomenological consequences. A very interesting analysis regarding the violation of the equivalence principle for gravitational couplings of neutrinos revealed that there is no allowed region of parameter space which can explain the existing data.

The study of dusty plasmas which has been of interest lately has been pursued to investigate the role of dust charge dynamics on the low frequency behaviour of the plasma, particularly in damping Alfvén waves. Such effects may have important consequences for interstellar clouds. Using kinetic theory, it has been found that the small amplitude dust acoustic waves are governed by KdV equation and the soliton amplitude and width as obtained here differ significantly from their counterparts in the fluid model.

Classically chaotic multi-dimensional anharmonic oscillators have been studied as models of quantum chaos with emphasis on the properties of localized scarred eigenfunctions. Relaxation fluctuations in quantum chaos have been shown to have quasi-universal features. Asymptotic studies of Gauss sums have been carried out as a model of semi-classical trace formulas relevant to quantum chaos.

A hybrid approach,incorporating nonlinear dynamics and artificial neural networks has been proposed to model complex time series. This methodology has been applied to computer generated data,as well as sunspot occurrences.

The PRL General Circulation Model was used for sensitivity studies with changes in the boundary conditions of the atmosphere such as sea surface temperature, surface albedo and soil moisture.

Laser Physics and Quantum Optics

The group continued with its major thrust in the area of optical manipulation of atoms leading to the prediction of sub-natural line-widths in spontaneous emission; the demonstration of transparency against two photon absorption; the control of the quantum jumps in atoms placed in a suitably designed cavity; the production of sub-Poissonian light as a result of competing single photon and two photon processes; explanation of the observed sub-Doppler light amplification.

Another major area of activity has been nonlinear quantum optics. Here a totally new source of realising parametric interactions (which are conventionally studied using non-linear crystals) was obtained in the form of Raman transitions among the vibrational degrees of freedom of an ion in a trap. Besides, a general approach to the formation of Schrödinger cat states was developed. The possibility of vacuum field induced filamentation was demonstrated. The phase conjugation at femtowatt power levels was demonstrated.

In the area of lasers, extensive work has been done on the novel design of low loss waveguide resonators; the demonstration of the gain enhancement in diode lasers by the injection of a weak optical signal; development of a homodyning technique for the measurement of both coherent and incoherent part of the spectrum.

Planetary Atmospheres and Aeronomy

The Planetary Atmospheres and Aeronomy Division's research activities cover investigations of a wide range of physical and chemical processes that occur in the earth's atmosphere and in other planetary and cometary atmospheres. These investigations are based on the measurements of atmospheric parameters using balloon, ocean cruise and rocket-borne experiments along with the remote sensing of the atmosphere by radio and optical techniques. Modest attempts are made in the atmospheric modelling and numerical simulation studies.

The research programme covers studies in middle atmosphere, upper atmosphere, planetary and cometary atmospheres and laboratory astrophysics. In the middle atmospheric studies, as a part of the joint international INDOEX (Indian Ocean Experiment) programme between PRL and the Scripps Institute of Oceanography, San Diego, U.S.A, surface measurements of ozone, carbon monoxide and methane along with aerosol properties and surface reaching solar radiation intensities were made during January-February 1996 and 1997 over the Indian ocean region. Systematic decrease of O_3 , CO_2 and aerosols (< 0.5 µm) were noticed from coastal to open ocean. Sharp increase around 5°N were noted which were associated with the polluted air from the sub-continent. Both the columnar optical depth and the mass concentration showed strong latitudinal gradient with decrease from coast to open ocean region. The coastal aerosols were found to be more absorbing than those found over the open ocean region. Under the Joint Global Ocean Flux Study (JGOFS) Programme an estimate of ocean - to - atmosphere flux of N_2O (0.56 - 0.76 Tg / Year) has been made from the measurements during inter-monsoon, north-east and south-west monsoons over the Arabian sea. Aerosol columnar optical depths, mass concentration and size distribution along with surface reaching solar flux measurements have been made over the Arabian sea during three ship cruises for the validation of the data from Modular Optoelectronic Scanner (MOS), a German payload onboard IRS-P3. It has been shown that the radiance values calculated from the actually measured aerosol size distribution compare better with the satellite measured radiance data than with the model values. Further, a chemical scheme has been suggested to explain the recent results of a HF partial reflection experiment at Scott Base, Antarctica which showed that, quite often a layer of electron density of about 1000 cm^3 is seen around 45km.

In the upper atmospheric studies, a major breakthrough has been, the first results on rotational temperatures in the mesopause region, obtained during 'daytime' from the hydroxyl emission measurements at 731.6 nm and 740.2 nm. The ground based multi-wavelength dayglow measurements at 589.6 nm, 557.7 nm and 630 nm have demonstrated that the thermospheric contribution to 557.7 nm during daytime reaches as high as 70% on most of the occasions as compared to less than 20% during nighttime in conformity with the UARS satellite results. The neutral temperatures measured by ground based spectroscopic observations and from DE-2 satellite have been used in a correlative study with the D_{st} magnetic index. By appropriately parameterizing the D_{st} into the existing atmospheric model the hitherto unexplained variabilities have been reproduced successfully both during high and low solar epochs. The Wind and Temperature Spectrometer (WATS) data from DE-2 satellite has been used to study the recently discovered phenomenon of Equatorial Temperature and Wind Anomaly (ETWA). The maximum zonal wind is shown to occur over the dip equator and not over the geographic equator. The maximum acceleration is around 17-18 LST and maximum velocity around 20 LST and is independent of solar flux and magnetic activity. The stronger the zonal wind and/or the ionization crest, the larger the temperature anomaly and usually attaining maximum strength around 19-20 LST clearly bringing out the role of ion-drag in the generation of ETWA. Following the concern that the increased concentration of trace gases in the lower atmosphere would result in changes in upper atmosphere and ionosphere too, ionospheric data over Ahmedabad during past four decades were examined to find any long term trend in its variabilities. The critical frequency of F layer and the peak altitude of F layer (h_pF_2) do not show any significant change in this period. An examination of the strength of the equatorial electrojet as determined by the ground geomagnetic measurements and calibrated by rocketborne measurements to currents in the American and Indian longitude regions has revealed that the longitudinal inequality in currents is only about 23 per cent which is mainly contributed by the larger electron velocity in the American region. This would amount to lower electric field there which has been confirmed by recent satellite measurements. Further, non-linear numerical simulation studies of Equatorial Spread-F (ESF) have been carried out to explain the downward drifting of radar plumes associated with ESF as detected from the MST radar observations at Gadanki. Also, in-situ electron density measurements made from SHAR during 4 October 1988 under strong spread-F has shown large scale vertical structures below 150 km, structures of few kms to few tens of kms in the region 150 - 250 km suggesting the role of gravity waves influencing such structures. Apart from the terrestrial environment, detailed theoretical studies on the chemical processes in the atmosphere of Mars and Comets are also being carried out.

In the Laboratory Astrophysics Group, the study of temperature dependence of photoabsorption cross sections of SO_2 has been carried out in the spectral region 188 - 220 nm at temperatures ranging from 220 to 300 K. Also, during the year, total electron scattering cross sections for carbon monoxide and nitrous oxide have been measured at low electron energies (0 - 10 eV) using a photoelectron source. Radiative life time measurements of NO_2 have also been made by photon impact using an excimer laser-pumped tunable dye-laser. Fluorescence excitation spectrum of NO_2 has been studied and time resolved measurements of fluorescence decay curves have been made to obtain radiative life times.

Earth Sciences and Solar System Studies

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

Ar-Ar measurements of carbonatites from Amba Dongar in Gujarat and Sung valley in Meghalaya were carried out to determine the chronology and mechanism of their formation. The results show that the Amba Dongar carbonatites are 65.0±0.3 Ma. These ages are consistent with the plume origin hypothesis for the formation of the Cretaceous alkaline carbonatite complexes in India.

Detailed studies of carbonate exposures from the Lesser Himalaya were made to assess their contribution to the high radiogenic Sr isotope composition of the source waters of the Ganga and the Indus.The results suggest that although the Sr isotope composition of many of these carbonates have been modified by post depositional process, they are unlikely to be a major contributor to the radiogenic Sr isotope composition of the Ganga and Indus. Silicate weathering seems to be the source of high $^{87}Sr/^{86}Sr$ in these rivers.

The group examined the long term rates of mobility of transverse dunes in NW Thar desert using Infra-red stimulated dating technique. The results indicate a multifold increase in the dune mobility rate during the past few centuries compared to the average dune mobility rates during 500-2000 years ago. The current higher mobility rate is attributed to decrease in local vegetation cover. The group also established that the aeolian activity in the Thar desert began atleast 150,000 years ago ruling out anthropogenic origin of this desert.

Evolutionary history of the atmosphere of Mars, obtained from the study of a martian meteorite collected from Antarctica, revealed that by 4 ba ago xenon has fully evolved in the Martian atmosphere, while ^{40}Ar took longer time to degas from the interior of the planet and nitrogen is being continuously lost from the atmosphere.These conclusions are consistent with the hydrodynamic escape model.

Observations of the meteor trail, petrogenetic and chemical history and cosmogenic effects of the eucrite Piplia Kalan which fell in Rajasthan in June 1996 allowed an estimation of its orbital parameters. The deduced orbit agrees with the proposition that eucrites come from the inner asteroidal belt, probably asteroid 4 Vesta. The study revealed that it is a monomict, brecciated , thermally equilibriated, non-cumulate eucrite following the Nuevo Laredo trend, which formed very early (simultaneously or within a few million years) after the formation of the solar system.

Studies on the origin and causes of geologic boundaries and evolution of the Indian lithosphere, revealed that (i) Absence of impact ejecta at the Cretaceous-Tertiary boundary at Anjar does not support the hypothesis of a large impact at the India-Syechelles boundary (named the Shiva Crater) or another crater proposed near Bombay, (ii) ^{40}Ar-^{39}Ar ages of the mafic volcanics from Himalaya provided the first direct evidence for reactivation of pre-existing faults in Himalaya, (iii) First ever measurement of nitrogen composition in tektites confirms sedimentary rocks as their source, (iv) Sr isotopic study of alkaline rocks and carbonatites of Amba Dongar complex shows that they are genetically related and parent magma of these rocks evolved through liquid immiscibility and wall rock-assimilation and (v) A gabroic body in Garhwal Himalaya is dated to be 1989 Ma by Rb-Sr method. This age coincides with the cluster in ages on granitoids in the region. This type of basic-acidic magmatism is quite common in rift related Phanerozoic continental flood basalts. The present work shows similarities in tectonic processes in Phanerozoic as well as Proterozoic times.

Research Facilities

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 Telescope 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 Systems

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 IBMRS6000/580 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 faciliies 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	40
No. of Post Doctoral Fellows	15
No. of Project Scientists	3
No. of Project Associates	9

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	15

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	20
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	3
ii. electronics laboratory	3
iii. library	4
iv. maintenance	2
v. workshop	10
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	5
Papers published in journals	
(a) national	23
(b) international	87
Papers published in proceedings	38
Papers presented in symposia and schools etc.	
a. national	110
b. international	62
Invited/Review talks given	71

Books/Journals Edited

1. **Krishnaswami, S. and Nair, R.R., "JGOFS (India) Collected Papers", Current Science, 71, 831-905, 1996.**
2. **Singhvi, A.K. and Thomas, D.S.G., "Proceedings of International Symposium on Evolution of Deserts", Part II, Journal of Arid Environments, Vol. 32(1), 90, Academic Press, UK, 1996.**

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. PRL Golden Jubilee Symposium on Gravitation and Particle Physics, December 10-14, 1996. (Conveners: A.R. Prasanna, A.S. Joshipura and U. Sarkar).
2. PRL Golden Jubilee Workshop on Solar Physics in India during the Next Solar Maximum and Beyond, October 7-10, 1996 (Conveners: A. Ambastha and A. Bhatnagar)
3. Workshop on Perspectives in Atmospheric Chemistry, December 26-27, 1996 (Conveners: Shyam Lal and H. Chandra).
4. Symposium C2.1: "Permanent Changes in the Ionosphere and Middle Atmosphere", 31st COSPAR Scientific Assembly, Birmingham, U.K., July 14-21, 1996 (Main Scientific Organiser: D.K. Chakrabarty and Deputy Scientific Organiser: R. Sridharan).
5. Symposium C2.3: "Electrodynamics of the Low and Sub-auroral Middle Atmosphere", 31st COSPAR Scientific Assembly, Birmingham, U. K., July 14-21, 1996 (Main Scientific Organiser: S. P. Gupta).

Distinguished Visitors at PRL

Prof. W.E. Lamb, **Nobel Laureate**, from Optical Sciences Centre, University of Arizona, Tucson, USA visited PRL as the nineteenth Vikram A. Sarabhai Professor. During his visit he gave three lectures and a popular lecture on the Discovery of the Anomalous Fine Structure of Hydrogen.

Prof. Jörg Eichler, from Hahn - Meitner - Institut Berlin, Germany visited PRL as the eighteenth Vikram A. Sarabhai Professor. During his visit he gave two lectures and a popular lecture on the New Atomic Physics with Highly-Charged Heavy Ions.

Prof. U.R. Rao, Chairman, PRL Council of Management delivered the ninth Prof. K.R. Ramanathan Memorial Lecture entitled Space Technology for Changing the State of the World on November 20, 1996.

Prof. C.N.R. Rao, F.R.S., Albert Einstein Research Professor and President, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore delivered the tenth Prof. K.R. Ramanathan Memorial Lecture entitled Giant Magnetoresistance and Charge-Ordering in Oxides on December 26, 1996.

As a part of the Golden Jubilee Year Celebrations a number of distinguished visitors were invited. They were Prof. M. Leduc, France; Prof. S. R. Pottasch, Netherland; Prof. C. V. Vishveshwara, India; Prof. Paul Crutzen, **Nobel Laureate**, Germany; Prof. E. Wolf, USA and Prof. P. Lena, France. The visitors had extensive interactions with the PRL scientists. They also delivered public lectures.

Seminars and Colloquia Held

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

Seminars held	80
Colloquia held	30

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

To mark the Golden Jubilee Year celebrations the laboratory organised popular lectures by internationally renowned scientists.

Popular lectures organised	10

Administrative Support

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

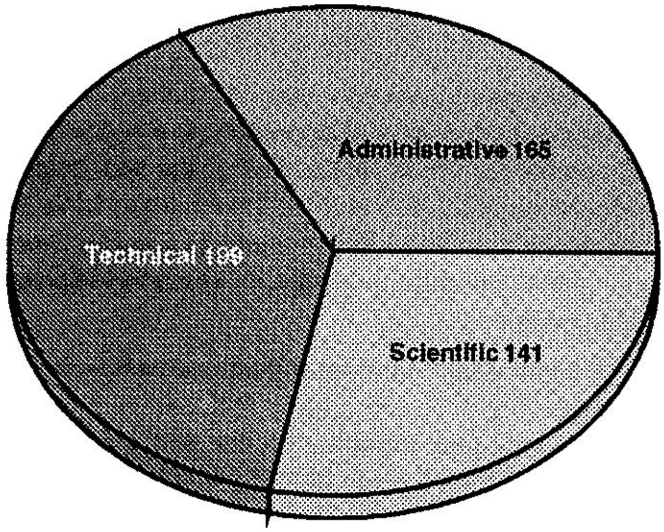


Fig.1.1 Staff Structure of PRL

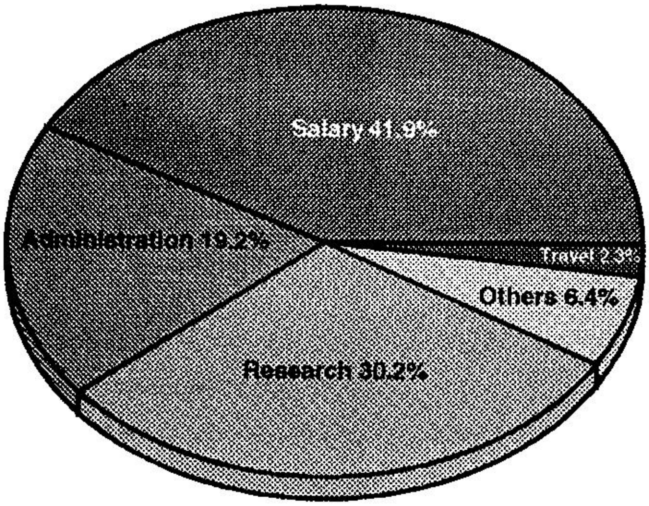


Fig.1.1 PRL Budget

Miscellaneous

PRL celebrated the Vikram Jayanti on August 12, 1996 to mark the seventy eighth birthday of Dr. Vikram Sarabhai. The Hari Om Ashram Prerit Dr. Vikram Sarabhai Research Awards were presented to six distinguished scientists by Dr. K. Kasturirangan, Chairman, Indian Space Research Organisation and Secretary, Department of Space.

The National Science Day Celebration was organised at PRL in association with the Ahmedabad Chapters of Indian Physics Association and INSA on February 23, 1997. 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.

As a part of implementation and progressive use of Hindi in PRL, the Hindi Week was celebrated at PRL from September 16-30, 1996. The highlights of the celebrations included word quiz, essay, elocution, debate, poetry and recitation competitions, including self written poetry and Antakshari. All staff members alongwith their families were invited in some of the programmes to make this celebration attractive. The Hindi cell also participated in Hindi Workshops and Rajbhasha Sammelans held in Spce Applications Centre (SAC) and Gujarat Vidyapeeth, both at Ahmedabad and at Indore. At SAC an invited paper on Appointment, Posting, Promotion: Hindi Teaching Scheme was presented by the Hindi cell.

The Golden Jubilee Year celebration was launched with the release of a colorful brochure, **50 Years of PRL,** and a video **PRL at 50**.

As a part of the Golden Jubilee Year Celebrations, PRL organised Inter Centre Outdoor Games of Department of Space from December 14 to 20, 1996. Nearly seven hundred participants including women took part in football, hockey, tennis, basketball etc. PRL also sent its contingents in all the DOS games. PRL tennis team bagged the second prize and Dr. M.M. Sarin was adjudged the best player from PRL.

In the Athletics meet held at VSSC, Trivandrum, Miss Leela Iyer received the second prize in shotput. In Indoor games held at ISAC, Bangalore, Mr. A.J. Shroff received the first prize in Chess competition.

Awards and Honours

Prof. U.R. Rao, Honorary Fellow, PRL was awarded

a. the International Vikram Sarabhai Award for 1996 during the 31st Committee on Space Research (COSPAR) Scientific Assembly, held at Birmingham, UK on July 15, 1996.

b. the S.K. Mitra Birth Centenary award during the 84th Annual Science Congress held in New Delhi on January 3, 1997.

c. the Yudhvir Foundation Award for 1997.

Prof. D. Lal, Honorary Fellow, has been awarded

a. the C.V. Raman Birth Centenary award during the 84th Annual Science Congress held in New Delhi on January 3, 1997.

b. the Geochemical Society's V. M. Goldschmidt Medal for 1997.

Prof. G.S. Agarwal has been

a. elected Fellow of the Third World Academy of Sciences, ICTP, Italy.

b. awarded the R.D.Birla Award of the Indian Physics Association for 1996.

Dr. D. P. Dewangan has been elected Fellow of the National Academy of Sciences, Allahabad.

Prof. B.L.K. Somayajulu, has been awarded the Jawaharlal Nehru Birth Centerary Lecturership by the Indian National Science Academy for the year 1997.

Prof. G.S. Agarwal has been invited to be

a. a Member, Advisory Committee International Conference on Squeezed States, Budapest.

b. a Member, Advisory committee, Wigner Symposium, Vienna.

c. Director, Winter College on Quantum Optics : Novel Radiation Sources, International Center for Theoretical Physics, Italy, 3-21 March 1997.

Shri H. S. Mazumdar has been awarded a cash prize for the invention of *Computer Aided Woven Designing Package with Computer Controlled Sample Handloom* by C. D. Foundation Trust, Bombay on March 8, 1997.

A Certificate of Merit was awarded to the paper on **Sr isotopic systematics of Ambadongar alkaline rocks : Evidence for liquid immiscibility and wall rock assimilation** by J.S. Ray and J.R. Trivedi at the 7th National Symposium on Mass Spectrometry at Gwalior, November, 1996. This paper was adjuged for the **FIRST** place in the Session.

The paper titled **Charging of dust grains by a flowing plasma** by S.B. Banerjee, R.K.Varma and A.M. Punithavelu was adjudged as the best poster at the International Conference on Dusty Plasmas, held in October 1996 at Goa.

Papers Published in Journals in 1996-97

Astronomy and Astrophysics

1. Baliyan K.S., Joshi U.C. and Deshpande M.R., "On the Variability Timescales and Magnetic Field in OJ 287", Astrophys. & Space Sci., **240** (1996).
2. Debi Prasad C., Ambastha A., Srivastava Nandita and Tripathy S. C., "Chromospheric Evolution and the Flare Activity of Super-Active Region NOAA 6555", J. Astrophys. Astr., **18**, 1 (1997).
3. Joshi U.C., Baliyan K.S., Ganesh S., Chitre A., Vats Hari Om and Deshpande M.R., "The Polarization Study of Comet Hyakutake C/1996 B2", Astron. & Astrophys., **319**, 694 (1997).
4. Joshi U.C., Manian K.S.B., Chauhan J.S., Shah Vishal, Chitre Aparna,Ganesh S. and Deshpande M.R., "A Near Infrared Polarimeter for Astrophysical Study", BASI, **25**, 133 (1997).
5. Joshi U.C., Ganesh S., Baliyan K.S. and Deshpande M.R., "Molecular Band Polarization in Comet Hyakutake C/1996 B2", Current Sci., **71**, 624 (1996).
6. Ragland Sam, Chandrasekhar T. and Ashok N.M., "Detection of Circumstellar Dust Shell around Supergiant TV Gem from Milliarcsecond Resolution Near Infrared Observations", Astron. & Astrophys., **319**, 260 (1997).
7. Vats Hari Om, Deshpande M.R., Calla O.P.N., Vadher N.M., Darji B.M. and Sukumaran V., "Microwave Bursts from Jupiter due to K, N, P2 and S. Fragments", Earth, Moon and Planets, **73**, 125 (1996).
8. Vats Hari Om, Deshpande M.R., Iyer K.N., Kondo T. and Isobe T., "Solar Radio Burst on 30 September 1993", Ind. J.Radio Space Phys., **25**, 28 (1996).
9. Vats Hari Om, Deshpande M.R., Calla O.P.N., Vadher N.M., Darji B.M. and Sukumaran V., "Peculiar Oscillations in the Microwave Emission of Jupiter during the Impact of K-fragment of Comet Shoemaker-Levy 9", Earth Moon & Planets, **74**,1 (1997).

Theoretical Physics

Gravitation Physics and Astrophysics

10. Ehlers, J. and Prasanna A.R., "A WKB Formalism for Multicomponent Fields and Its Application to Gravitational and Sound Waves in Perfect Fluids", Classical and Quan. Gravity, **13**, 2231(1996).
11. Banerjee, D., Bhatt, J., Das, A.C. and Prasanna A.R., "Axisymmetric Magnetohydrodynamic Equilibrium around a Magnetized Schwarzschild Blackhole", Ap. J., **474**, 389 (1997).
12. Gupta Anshu, Iyer Sai and Prasanna A.R., "Centrifugal Force and Ellipticity Behaviour of a Slowly Rotating Ultra Compact Object", Classical and Quantum Gravity, **13**, 2675 (1996).
13. Prasanna A.R., "Inertial Frame Dragging and Mach's Principle in General Relativity", Classical and Quantum Gravity, **14**, 227 (1997).
14. Gupta Anshu, Iyer Sai and Prasanna A.R., "Behaviour of Centrifugal Force and of Ellipticity for a Slowly Rotating Fluid Configuration with Different Equations of State", Class. and Quant. Gravity, **14**, 143 (1997).

Atomic and Molecular Physics

15. Dewangan, D.P., "Recent Developments in Charge Transfer in Energetic Ion-Atom Collisions", in Atomic, Molecular and Cluster Physics (Ed. S.A. Ahmad, Narosa Publishing House, New Delhi, India, 1997), p. 220-236.

High Energy Physics

16. Joshipura, A.S., Chun, E.J. and Smirnov A. Yu., "Quasi Goldstone Boson as Sterile Neutrino", Phys. Rev., **D54**, 4654 (1996).
17. Datta, G. and Joshipura A.S., "Automatic CP Invariance with Flavour Symmetry", Int. Journal of Mod. Phys. Lett., **A11**, 1869 (1996).
18. Ravindran, V., "Order $\alpha_s(Q^2)$ QCD Corrections to the Polarised $e^+ e^- \to \Lambda X$", Phys. Letters, **B398**, 169 (1997).
19. Ravindran, V., "The Polarised Λ Production in QCD",. Nuclear Physics, **B490**, 272 (1997).
20. Poulose, P. and Rindani, S.D., "Decay-lepton Angular Distribution in Polarized $e^+ e^- \to t\bar{t}$ and CP-violating Dipole Couplings of the Top Quark", Physical Review, **D54**, 4326 (1996).

21. Poulose, P. and Rindani, S.D., "Simple Decay-Lepton Asymmetries in Polarized $e^+ e^- \to t\bar{t}$ and CP-violating Dipole Couplings of the Top Quark", Phys. Lett., **B383**, 212 (1996).
22. Sarkar, U. and Mann, R.B., "Test of Equivalence Principle from Neutrino Experiments", Phys. Rev. Lett., **76**, 865 (1996).
23. Sarkar, U., Ganguly, A. and Parikh, J.C., "Low Energy Leptogenesis in Left-Right Symmetric Models", Phys. Lett., **B385**, 175 (1996).
24. Sarkar, U., Flanz, M., Paschos, E.A. and Weiss, J., "Baryogenesis through Mixing of Heavy Majorana Neutrinos", Phys. Lett., **B389**, 693 (1996).
25. Sengupta, S., Bhatt, J.R., Kaw, P.K. and Parikh, J.C., "Collective Thermalization in Quark Gluon Plasma", Pramana, **48**, 655 (1997).
26. Sheel V., Mishra H. and Parikh J.C., "Hadronic Correlators and Condensate Fluctuations in QCD Vacuum", Phys. Lett., **B382**, 173 (1996).

Nuclear Physics

27. Devi, Y.D. and Kota, V.K.B., "M1 Distributions for ^{163}Dy and ^{157}Gd in $SU^{BF}_{sdg}(3)$ and $SU^{BF}_{sd}(3) \times$ lg Limits of pn-sdgIBFM", Nuc. Phys., **A600**, 20 (1996).
28. Kota, V.K.B. and Majumdar, D., "Application of Spectral Averaging Theory in Large Shell Model Spaces : Analysis of Level Density Data of fp-Shell Nuclei", Nucl. Phys., **A604**, 129 (1996).
29. Kota, V.K.B., "Applications of the SU(3) Dynamical Symmetry of Interacting Boson Model", Rev. Mex. Fis. **42**, 131 (1996).

Non-linear Dynamics and Computational Physics

30. Lakshminarayan A., Santhanam M.S. and Sheorey V.B., "Local Scaling in Homogeneous Hamiltonian Systems", Phys. Rev. Lett., **76**, 396 (1996).
31. Sheorey V.B., Santhanam M.S. and Lakshminarayan A., "Identification of Localized States in Chaotic Quantum Systems", Molec. Phys., **88**, 325 (1996).
32. 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.
33. Santhanam M.S., Sheorey V.B. and Lakshminarayan A., "Chaos and Localization in Coupled Quartic Oscillators", Pramana, **48**, 439 (1997).
34. Lakshminarayan A., "Accuracy of Trace Formulas", Pramana, **48**, 517 (1997).
35. Krishnan R. and Kasture S.V., "Modulation of Low Frequency Intraseasonal Oscillations in Northern Summer Monsoon by El Nino and Southern Oscillation (ENSO)", Journal of Meteorology and Atmospheric Physics, **60**, 237 (1996).
36. Bannur V.M., Kaw P.K. and Parikh J.C., "Statistical Mechanics of Quartic Oscillators", Phys. Rev., **E55**, 2525 (1997).
37. Kulkarni D.R., Parikh J.C. and Pratap R., "Simulation of Charateristics and Artificial Neural Network Modelling of Electro-encephalograph Time Series"., Phys. Rev., **E55**, 4508 (1997).

Plasma Physics

38. Bhatt, J.R., "Langmuir Waves in a Dusty Plasma with Variable Grain Charge", Physical Review, **E55**, 1166 (1997).
39. Rao, N.N., "Coupled Scalar Field Equations for Nonlinear Wave Modulations in Dispersive Media", (**Review Paper**), Pramana **46**, 161 (1996).
40. Rao, N.N., "Dimensional Analysis", Resonance, **1**, 29 (1996).
41. Rao, N.N., "Integrability of Coupled Upper-hybrid and Magnetoacoustic Modes in a Magnetized Plasma", Phys. Scripta, **T63**, 219 (1996).
42. Antani, S.N., Kaup, D.J. and Rao, N.N., "Excitation of Upper-hybrid Waves from Ordinary-mode Electromagnetic Waves via Density Gradient in the Ionosphere", J. Geophys. Res., **101**, 27035 (1996).
43. Shukla, P.K. and Rao, N.N., "Coulomb Crystallization in Colloidal Plasmas with Streaming Ions and Dust Grains", Phys. Plasmas, **3**, 1770 (1996).
44. Shukla, P.K. and Rao, N.N., "Integrability of Nonlinearly Coupled Helicons and Phonons in Strongly Magnetized Dispersive Media", Phys. Letts., **A217**, 289 (1996).
45. Vidhya Lakshmi, S., Bharuthram, R., Rao, N.N. and Shukla, P.K., "Kinetic Theory of Nonlinear Dust-

acoustic Waves in a Dusty Plasma", Planet. Space Sci., **45**, 355 (1997).

Laser Physics and Quantum Optics

46. Vemuri G., Agarwal G. S. and Nageswara Rao B.D.,"Sub-Doppler Resolution in Inhomogeneously Broadened Media using Intense Control Fields", Phys. Rev., A **53**, 2842 (1996).
47. Lange W., Agarwal G. S. and Walther H., "Observation of Two-Photon Decay in a Driven Cavity", Phys. Rev. Lett., **76**, 3293 (1996).
48. Davis W.V., Gaeta A.L., Boyd R.W. and Agarwal G. S., "Statistical Noise Properties of an Optical Amplifier Utilizing Two Beam Coupling in Atomic Potassium Vapor", Phys. Rev., **A 53**, 3625 (1996).
49. James Daniel and Agarwal G. S., "The Generalized Fresnel Transform and Its Application to Optics", Opt. Comm., **126**, 207 (1996).
50. Huang H., Agarwal G. S. and Scully M.O., "Interference of Radiation from Two Trapped Atoms - Thermal Noise and Visibility", Opt. Comm., **127**, 243 (1996).
51. Puri R.R. and Agarwal G. S., "Unitarily Inequivalent Classes of Minimum Uncertainty States of SU(1,1)", **Invited** Paper to the H. Umezawa Memorial Issue of Int. J. Mod. Phys. B. **10**, 1563 (1996).
52. Agarwal G.S. and Singh R.P., "Complementarity and Phase Distributions for Angular Momentum Systems", Phys. Lett. **A 217**, 215 (1996).
53. Agarwal G.S. and Harshawardhan W., "Enhancement and Inhibition of Two Photon Absorption", Phys. Rev. Lett., **77**, 1039 (1996).
54. Lanzerotti M.Y., Schirmer R.S., Gaeta A.L. and Agarwal G.S., "Phase Conjugation of Very Weak Continuous Wave Optical Signals", Phys. Rev. Lett., **77**, 2202 (1996).
55. Agarwal G.S., Lehner J. and Paul H., "Invariances for States of Light and their Quasi-Distributions", Opt. Comm., **129**, 369 (1996).
56. Vemuri G., Vasavada K.V. and Agarwal G.S., "Coherence Induced Effects in Pulse-Pair Propagation Through Absorbing Media", Phys. Rev., **A 54**, 3394 (1996).
57. Agarwal G.S. and Chaturvedi S.C., "A Non-group Theoretic Proof of the Completeness of Arbitrary Coherent States D(α)|f>", Int. J. Mod. Phys., **A 11**, 2083 (1996).
58. Vemuri G., Agarwal G.S. and Nageswara Rao B.D., "Analysis of Sub-Doppler Line Widths in Inversionless Amplification", Phys. Rev., **A 54**, 3695 (1996).
59. Agarwal G.S. , "Control-laser-induced Sub-natural Line Widths and Quenching of Spontaneous Emission", Phys. Rev., **A 54**, Rapid Communication, 3734 (1996).
60. Agarwal G.S. and Wolf E., "Correlation-Induced Spectral Changes and Energy Conservation", Phys. Rev. **A 54**, 4424 (1996).
61. Jyotsna I.V. and Agarwal G.S., "Fractional Revivals in Optical Parametric Interactions", J. Mod. Opt., **44**, 305 (1997).
62. Nagasako E., Boyd R.W. and Agarwal G.S., "Quantum Fluctuations Induced Laser Beam Filamentation", Phys. Rev., **A 55**, 1412 (1997).
63. Agarwal G.S. and Vemuri G., "Wigner Distribution for Density of States in Quantum Optics", Phys. Rev., **A 55**, 1466 (1997).
64. Harshawardhan W. and Agarwal G.S.,"Multiple Landau-Zener Crossing and Quantum Interference in Atoms Driven by Phase Modulated Fields", Phys. Rev., **A 55**, 2165 (1997).
65. Agarwal G.S., "Physical Picture of Spontaneous Emission Cancellation", Phys. Rev., **A 55**, 2457 (1997).
66. Agarwal G.S., "Nature of the Quantum Interference in Electromagnetic Field Induced Control of Absorption", Phys. Rev. **A 55**, 2467 (1997).
67. Scully M.O., Rath U.W., Su C. and Agarwal G.S., "On Enhancing Spectral Resolution Via Correlated Spontaneous Emission", Opt. Commun., **136**, 39 (1997).

Planetary Atmospheres and Aeronomy

68. Acharya Y. B. and Agarwal A. K., "Logarithmic Current Electrometer using Light Emitting Diodes", Measure. Sci. & Technology (U.K.), **7**, 151 (1996).

69. Acharya Y. B and Agarwal A. K. "Analytical Correction of Temperature in a Logarithmic Electrometer using Light Emitting Diodes", Review of Sci. Instruments, **67**, 2014 (1996).

70. Chakrabarty D. K., "Variability of Mesospheric Nitric Oxide at Low Latitude", Advances in Space Research, **17**, 77 (1996).

71. Chakrabarty D. K., and Peshin, S. K., "Behaviour of Ozone over Indian Region after Pinatubo Eruption", J. Geophys. Res., **102**, 153 (1997).

72. Chandra H., Vyas G.D., Sinha H.S.S., Prakash, S. and Misra, R.N., "Equatorial Spread-F Campaign over SHAR", J. Atmos. Terr. Phys., **59**, 191 (1997).

73. Chandra H., Vyas, G.D. and Sharma, S., "Ionospheric Effects of the Total Solar Eclipse of 24 October 1995 over Ahmedabad", Ind. J. Radio & Space Phys., **26**, 30 (1997).

74. Fabian P., Borchers R., Leifer R., Subbaraya B. H., Lal S. and Boy M., "Atmospheric Distribution of Halocarbons", Atmospheric Environment, **30**, 1787 (1996).

75. Dhopte N.P., Vali A., Navneeth G.N. and Chandra H., "HF Doppler Observations of Nighttime F-region over Nagpur", Ind. J. Radio & Space Phys., **25**, 271 (1996).

76. Gupta S. P., "Thin Layers of Ionisation Observed by Rocket-borne Probes in Equatorial E Region", Advances in Space Research, **19**, 169 (1997).

77. Haider S.A., "High Latitude Plasma Transport through the Martian Tail : Polar Wind", J. Geophys. Res., **101**, 24955 (1996).

78. Haider S.A., "Chemistry of the Nightside Ionosphere of Mars", J. Geophys. Res., **102**, 407 (1997).

79. Jayaraman A., Acharya Y. B., Chandra H., Subbaraya B. H., Ramachandran S and Ramaswami S., "Laser Radar Study of the Middle Atmosphere over Ahmedabad", Ind. J. Radio and Space Phys., **25**, 318 (1996).

80. Lal S., Patra P.K., Venkataramani S. and Sarin M.M., "Distribution of Nitrous Oxide and Methane in the Arabian Sea", Curr. Sci., **71**, 894 (1996).

81. Manish Naja and Shyam Lal, "Changes in Surface Ozone Amount and its Diurnal and Seasonal Patterns from 1954-55 to 1991-93 Measured at Ahmedabad (23° N), India", Geophys. Res. Lett., **23**, 81 (1996).

82. Prahlad V., Ahmed S.M. and Kumar V., "Temperature Dependence of Photoabsorption Cross Sections of Sulphur Dioxide at 280-320 nm", J. Quant. Spectrosc. Radiat. Transfer, **56**, 57 (1996).

83. Rastogi R.G., Chandra H. and James M.E., "Nocturnal Variations of Geomagnetic Horizontal Field at Equatorial Stations", Geophys. Res. Lett., **23**, 2603 (1996).

84. Rastogi R.G., Chandra H. and James M.E., "On the Disintegration of the Vortex Structure of Ionospheric Current System Along Asian Longitude Sector", J. Geomag. Geoelectr., **48**, 148 (1996).

85. Sekar R. and Raghavarao R., "A Case Study on the Evolution of Equatorial Spread-F by a Nonlinear Numerical Model using the Results from a Set of Coordinated Measurements", J. Atmos. Terr. Phys., **59**, 343 (1997).

86. Suresh T., Desai E., Desai P., Jayaraman A. and Mehra P., "Photosynthetically Available Radiation in the Arabian Sea", Current Science, **71**, 883 (1996).

87. Thomas L., Marsh A.K.P., Wareing D.P., Astin I. and Chandra H., "VHF Echoes from the Mid-latitude Mesosphere and the Thermal Structure Observed by Lidar", J. Geophys. Res., **101**, 12867 (1996).

Earth Sciences and Solar System Studies

Oceanography and Climate Studies

88. Chakraborty, S. and Ramesh, R., "Environmental Significance of Stable Carbon and Oxygen Isotope Ratios of Banded Corals from Lakshadweep, India", Quaternary International, **37**, 55 (1997).

89. Church, T.M., Sarin, M.M., Fleisher, M.Q. and Ferdelman, T.G., "Salt Marshes: An Important Coastal Sink for Dissolved Uranium", Geochem. et Cosmochim Acta, **60**, 3879 (1996).

90. Datta, P.S., Bhattacharya, S.K. and Tyagi, S.K., "^{18}O Studies on Recharge of Phreatic Aquifers and Groundwater Flow-paths of Mixing in the Delhi Area",

Journal of Hydrology, **176**, 25 (1996).

91. Komothi, M.M. and Juyal, N., “Environmental Impact Assessment of a Few Selected Watersheds of the Chamoli District (Central Himalaya) using Remotely Sensed Data”, Int. Jour. Remote Sensing, **17**, 1391 (1996).
92. Koul, D.K., Singhvi, A.K., Nambi, K.S.V. and C.L. Bhatt, “Feasibility of Estimating Firing Temperatures using 110°C TL Peak of Quartz”, Int. J. Appl. Rad. and Isotopes, **47**, 191 (1996).
93. Kumar,S., Prakash, B., Manchanda, M.L., Singhvi, A.K. and Srivastava, P., “Holocene Landform and Soil Evolution of the Western Gangetic Plains: Implications of Neotectonics and Climate”, Z. Geomorph., **103**, 283 (1996).
94. Bose, P. K., Sarkar, S. and Bhattacharya, S.K., “Dissolution Seams: Some Observations from the Proterozoic Chanda Limestone, Adilabad, India”, Carbonates and Evaporites, **11**, 70 (1996).
95. Sarin, M.M., Rengarajan, R. and Ramaswamy, V., “^{234}Th Scavenging and Particle Export Fluxes from the Upper 100m of the Arabian Sea”, Curr. Sci., **71**, 888 (1996).
96. Sarkar, A., Roy, A., Ghatak, G.S. and Bhattacharya, S.K., “Strontium Isotope Study of Krol-Tal Carbonates: Implications to the Strontium Isotope Flux of Himalayan Rivers”, Indian Jour. of Geology, **68**, 255 (1996).
97. Singhvi, A.K. and Krebetschek, M.R., “Luminescence Dating : A Review and a Perspective for Arid Zone Sediments”, Annals of Arid Zone, **35**, 249 (1996).
98. Somayajulu, B.L.K., “ ^{10}Be Melt Water Signal in Orca Basin Sediments, Gulf of Mexico”, Proc. Ind. Acad. Sci., **105**, 357 (1996).
99. Somayajulu, B.L.K., Sharma, P. and Naidu, A.S., “^{10}Be and Al Concentration in an Arctic Core: Implications to Climate and Sedimentation”, Curr. Sci., **70**, 1000 (1996).
100. Tandon, S.K., Sareen, B.K., Someshwar Rao, M. and Singhvi, A.K., “Aggradation History and Luminescence Chronology of Late Quaternary Semi-arid Sequence of Sabarmati Basin, Gujarat”, Palaeo., Palaeo., Palaeo., **128**, 329 (1997).

101 Yadav, D.N., “Manganese Mobilization from the Western Continental Margin of India”, Curr. Sci., **71**, 900 (1996).

Solar System and Geochronology

102. Bhandari, N., Shukla, P.N., Ghevariya, Z.G. and Sundaram, S.M., “K/T Boundary Layer in Deccan Intertrappeans at Anjar, Kutch”, Geological Society of America Special Paper, **307**, 417 (1996).
103. Bonino, G., Cini Castagnoli, G., Taricco, C. and Bhandari, N. “Century Scale Solar Variability Imprinted in the ^{44}Ti Activity in Meteorites”, Advances in Space Research, **17**, 127 (1996).
104. Goswami, J.N., Sinha, N., Murty, S.V.S., Mohapatra, R.K. and Clement, C.J.. “Nuclear Tracks and Light Noble Gases in Allan Hills 84001: Preatmospheric size, Fall Characteristics, Cosmic Ray Exposure Duration and Formation Age”, Meteoritics and Planet. Sci. **32**, 91 (1997).
105. Murty, S.V.S., Goswami, J.N. and Shukolyukov, Yu. A., “Excess ^{36}Ar in the Efremovka Meteorite: A Strong Hint for the Presence of ^{36}Cl in the Early Solar System”, Ap. J. **475**, 65 (1997).
106. Venkatesan, T.R., Kanchan Pande and Ghevariya, Z.G., “^{40}Ar-^{39}Ar Ages of Anjar Traps, Western Deccan Province (India) and its Relation to the Cretaceous-Tertiary Boundary Events”, Current Science, **70**, 990 (1996).
107. Wiedenbeck, M., Goswami, J.N. and Roy A.B., “An Ion Microprobe Study of Single Zircons from the Amet Granite, Rajasthan”, J. Geol. Soc. of India. **48**, 127 (1996).
108. Wiedenbeck, M., Goswami, J.N. and Roy, A.B., “Stabilization of the Aravalli Craton of Northwestern India at 2.5 Ga: An Ion Microprobe Zircon Study”, Chemical Geology, **129**, 325 (1996).
109. Venkatesan, T. R., Anil Kumar, Gopalan, K. and Muklamedov, A. I., “ ^{40}Ar-^{39}Ar Age of Siberian Basaltic Volcanism”, Chemical Geology, **138**, 303 (1997).

Electronics Laboratory

110. Rawal Leena P. and Mazumdar H. S., "A DSP based Low Precision Algorithm for Neutral Network using Dynamic Neuron Activation Function",CSI Communication,15 (April, 1996).
111. Mazumdar H. S. and Rawal Leena P., "A Learning Algorithm for Self Organised Multilayered Neural Network", CSI Communication, 5 (May, 1996).
112. Mazumdar H. S. and Rawal Leena P., " A Novel Algorithm for Simulation of a Robot using Neural Network", CSI Communication (August, 1996).

Papers Published in Proc. of Symposia / Schools

Astronomy and Astrophysics

1. Baliyan K.S., "Effect of Resonance in Electron and Photon Interaction with Atoms/ Ions", in "Atomic & Molecular Physics", Eds. S.P. Khare, Deo Raj & A Kumar, Bindra Pub. pp.70-85, (1997).
2. Chitre Aparna, Joshi U.C. and Srivastava J.B., "Multicolour Surface Photometry of Galaxies : Mrk 35 and Mrk 799", BASI, 24, pp.819-827, (1996).
3. Debi Prasad C., and Ashok Ambastha, "No Signature of Circum-Solar Dust Ring upto 5 Solar Radii from Optical Polarization and Near IR Observations of 24 October 1995 Total Solar Eclipse", Kodaikanal Obs. Bull., **1**, 1(1997).
4. Deshpande M.R., Joshi U.C., Baliyan K.S. and Ganesh S., "Microvariability in Blazars", Proceedings of the Sixth UN/ESA Workshop on Basic Space Science : Ground Based and Space Borne Astronomy at Bonn, Germany (1996).
5. Ganesh S., Chitre A., Vats H.O., Baliyan K.S., Joshi U.C., Deshpande M.R., and Shah A.B., "Polarization Observations of Hyakutake C/1996 B2", IAU Circular, 6371(1996).
6. Joshi U.C. and Chitre Aparna "Surface Photometry of Some Active Galaxies", Proceedings of Third East-Asian Meeting on Astronomy : Ground Based Astronomy in Asia, Ed. N.Kaifu, p218, (1996).
7. Joshi U.C. and Deshpande M.R., "Detection of Short Time Variability in BL Lac Object : OJ 287", Proceedings of Third East-Asian Meeting on Astronomy : Ground Based Astronomy in Asia, Ed. N.Kaifu, pp. 289, (1996).
8. Joshi U.C., Manian K.S.B., Chauhan J.S., Chitre Aparna, Shah Vishal M. and Deshpande M.R., "A Near Infrared Polarimeter for Astrophysical Study", Proceedings of Third East-Asian Meeting on Astronomy: Ground Based Astronomy in Asia", Ed. N.Kaifu, pp.375, (1996).
9. Kamath, U.S., Ashok N.M. and Chandrasekhar T., "Near Infrared Observations of Nova Aquilae 1995", Bull. Astr. Soc. India, **24**, 683 (1996).
10. Muthumariappan C., Anandarao B.G. and Banerjee D.P.K.,"Imaging Fabry-Perot Spectroscopic Observations on the Planetary Nebulae NGC 1514", Bull. Astr. Soc. India, **24**, 697, (1996).
11. Ragland Sam, Chandrsekhar T. and Ashok N.M., "Detection of Circumstellar Dust Shell Around Supergiant TV Gem from Milliarcsecond Resolution Near Infrared Observations",Bull. Astr. Soc. India, **24**, 725 (1996).
12. Singal A.K., "Cosmological Size Evolution of Extragalactic Radio Sources", IAU Cic., 175, ed. Ekers, R. et al., Reidel, Dordrecht, p.563 (1996).
13. Singal A.K., "A Proposal for Setting up a VLBI Station in India" , in Proc. IV APT Workshop, ed. King., E.A., ATNF, p.248 (1996).
14. Singal A.K., "Activities in India", in Proc. Tech. Workshop for APT and APSG 1996, ed. Takahashi, Y., CRL (1996).
15. Smith M.A., Murakami T. and Anandarao B.G., "Simultaneous X-ray, UV, and Optical Variations in l Eridani (B2e)", Bulletin of American Astronomical Society, Vol. 28, p.377, 1996.
16. S.C. Tripathy and J. Christensen-Dalsgaard, "Effects on Solar Structure of Opacity Changes". Bull.Astron.Soc.India, **24**, 129 (1996).
17. Tej Anandamayee, Chandrasekhar T., Ashok N.M., Ragland Sam, Mathur S.N. and Jain Jinesh, "CCD Imaging of Jupiter during its Impact with Comet Shoemaker-Levy 9: Obsevations from Jaiselmer", Bull. Astr. Soc. India, **24**, 639 (1996).
18. Vats Hari Om, Deshpande M.R., Iyer K.N., Kondo T. and Isobe T., "Meterwave Solar Bursts", Proc. SFRD Workshop, held at Hiraiso, Japan, January (1996).
19. Vats Hari Om and Singal A.K., "VLBI in India and International Collaboration", in Proc. Tech. Workshop for APT and APSG 1996, ed. Takahashi Y., CRL, pp.77 (1996).

Theoretical Physics

High Energy Physics

20. Sengupta S., Kaw P.K. and Parikh J.C., "Particle Simulation of Collective Thermalization in Quark Gluon Plasma", in Proc. Workshop on Quantum

Chromodynamics: Collision, Confinement and Chaos, Ed. H.M.Fried and B. Muller, World Scientific, Singapore (1997).

Nuclear Physics

21. Kota, V.K.B. and Parikh, J.C., "Group Theoretical Approach to Nuclear Collective Motion", in Physics of Rotating Nuclei, edited by S.N. Mukherjee and Y.R. Waghmare (New Age International Publishers, New Delhi, 1995), p. 171.
22. Devi, Y.D. and Kota, V.K.B., "New Signature for g-bosons in the Magnetic Dipole Strength Distribution of Deformed Odd Mass Nuclei", in The Structure of Medium-Heavy Mass Nuclei (Proc. of the RIKEN Symposium), edited by N. Onishi, T. Horibata, S. Yamaji and T. Kishida (RIKEN Publication, Japan, 1996), p. 94.
23. Kota, V.K.B., "Recent Developments in Statistical Nuclear Spectroscopy : Level Densities", in Recent Trends in Nuclear Structure Physics, edited by G. Shanmugam and N. Arunachalam (Published by M.S. University, Tirunelveli, India, 1997), p. 12.

Non-linear Dynamics and Computational Physics

24. Kasture, S.V., Biju Thomas and V. Satyan, "Study of Surface Albedo Changes and Hydrology in PRL-GCM", in Changes in Global Climate due to Natural and Human Activities, eds. S.N. Das and R.S. Thakur, Allied Publishers Limited, p. 231.
25. A. Lakshminarayan, M.S. Santhanam and V.B. Sheorey, "Exponentially Localized Eigenstates in Smooth Hamiltonian Systems", in 15th International Conference on Atomic Physics, Zeeman Effect Centenary, ZICAP, Amsterdam (1996).

Planetary Atmospheres and Aeronomy

26. Gupta S. P., "Electrodynamics of the Low and Sub-auroral Middle Atmosphere" - a report, COSPAR Bulletin, No. 137, 42-43, (1996).

Earth Sciences and Solar System Studies

Oceanography and Climate Studies

27. Bhattacharya, S.K., Jani, R.A., Mathur, V.K., Absar, A., Bodas, M.S., Gopendrakumar and Ravishanker., "Stable Carbon and Oxygen Isotopic Changes and Rare Earth Elements across Precambrian-Cambrian Boundary, Lesser Himalaya", Proc. Symp. NW Himalaya and Foredeep, 1995, Geol. Surv. India Spl. Publ. **21** (1), 225.
28. Ghosh, P., Bhattacharya, S.K. and Chakrabarti, A.,"Talchir Deposits in the Gondwana Basins of India and their Palaeoclimatic Significance", Proc. 7th Natl.Symp. on Mass-spectrometry (eds. S.K. Aggrawal and H.C. Jain), Indian Society for Mass-spectrometry, Mumbai, India, 383 (1996).
29. Padia, J.T., Pande, K., Ramesh, R. and Sharma, K.K., "Stable Isotope Study of Water Bodies in the Himalayan and Trans-Himalayan (Kashmir) region", Proc. 7th Natl. Symp. on Mass-spectrometry (eds. S.K. Aggrawal and H.C. Jain), Indian Society for Mass-specrtrometry, Mumbai, India, 436 (1996).
30. Padia, J.T. and Sharma, K.K., "Oxygen Isotopic Variations in a Speleothem from Jammu: Climatic Implications", Proc. 7th National Symposium on Mass-spectrometry (eds. S.K. Aggarwal and H.C. Jain), Indian Society for Mass-spectrometry, Mumbai, India, 436 (1996).
31. Ray, J.S. and Ramesh, R., "Stable Carbon and Oxygen Isotopes in Hydrothermally Altered Carbonatites, Amba Dongar, Gujarat", Proc. Seventh National Symp. on Mass-spectrometry (eds. S.K. Aggarwal and H.C. Jain), Indian Society for Mass Spectrometry, Mumbai, India, 394 (1996).
32. Singhvi, A.K., "Optically Stimulated Luminescence in Earth Sciences : A Status Report", Photostimulated Luminescence and its Applications, K. Govinda Rajan et al (eds)., Allied Publications, 87 (1996).
33. Sunil K Singh., J.R. Trivedi, Kanchan Pande and S. Krishnaswami, "Sr Isotopic and Chemical Composition of Carbonates from the Himalaya : Implications to Silicate versus Carbonate Weathering and Climate Change", in Proc. Seventh National Symposium on Mass-spectrometry (eds. S.K. Aggarwal and H.C. Jain), Indian Society for Mass-Spectrometry, Mumbai, India (1996).
34. R.K. Mohapatra and S.V.S. Murty, "Martian Atmospheric Component in the Antarctic Meteorite ALH 84001", in Proc. Seventh National Symposium on

Mass-spectrometry (eds. S.K. Aggarwal and H.C. Jain), Indian Society for Mass-Spectrometry, Mumbai, India (1996).

35. S. Sahijpal and J.N. Goswami, "Source(s) of Short-lived Nuclides in the Early Solar System : Constraint from Correlated Observation of ^{41}Ca on Mass Spectrometry", in Proc. Seventh National Symposium on Mass-spectrometry (eds. S.K. Aggarwal and H.C. Jain), Indian Society for Mass-Spectrometry, Mumbai, India (1996).

36. V.K. Rai and S.V.S. Murty, "Cosmic Ray Produced Nitrogen in Meteorites : An Experimental Approach", in Proc. Seventh National Symposium on Mass-spectrometry (eds. S.K. Aggarwal and H.C. Jain), Indian Society for Mass-Spectrometry, Mumbai, India (1996).

37. T. Ahmad, J.R. Trivedi and P.K. Mukherjee, "Rb-Sr age of Kepsar-Thayeli Gabroic Body, Garhwal Himalaya : Implications for Paleo-Proterozoic Basic-acidic Bimodal Magnetism in Himalaya", in Proc. Seventh National Symposium on Mass-spectrometry (eds. S.K. Aggarwal and H.C. Jain), Indian Society for Mass-Spectrometry, Mumbai, India (1996).

38. J.N. Goswami, S. Mishra, M.P. Deomurari, M. Wiedenbeck, S.L. Ray and A.K. Saha, "Zircon Geochronology of the Singhbhum-Orissa Craton, Eastern India : An Ion Microprobe Study", in Proc. Seventh National Symposium on Mass-spectrometry (eds. S.K. Aggarwal and H.C. Jain), Indian Society for Mass-Spectrometry, Mumbai, India (1996).

Theses Submitted during 1996-97

1. **Banerjee Debabrata**

   New Applications of Thermoluminescence (September 1996)

2. **Banerjee Devashis**

   Structure of Magneto Fluid Disk around a Compact Object (October 1996)

3. **Gupta Anshu**

   Studies of Fluid Distribution with Magnetic Fields, an Analysis of Ultra Compact Objects with Centrifugal Force Reversal (March 1997)

4. **Prasad Sushma**

   Late Quaternary Palaeoenvironment and Evolution of NAL region, Gujarat, India (September 1996)

5. **Sahijpal Sandeep**

   Isotopic Studies of the Early Solar System Objects in Meteorites by an Ion Microprobe (February 1997)

Papers Presented in Symposia / Schools in 1996-97

INVITED PAPERS/LECTURES

Astronomy and Astrophysics

1. "Near Infrared Astronomy with Infrared Arrays", at the Golden Jubilee Symposium at TIFR, Bombay on Perspectives of High Energy Astronomy and Astrophysics, August 1996 by **B.G.Anandarao**.

2. "Activities in India", at the Technical Workshop for APT and APSG at Kashima Space Research Centre, CRL, ***Kashima, Japan,*** December 10-13, 1996 by **A.K.Singal**.

Theoretical Physics

Gravitation Physics and Astrophysics

3. "Inertial Forces in General Relativity", at the Platinum Jubilee in Theoretical Physics, University of Delhi, March 26-28, 1996 by **A.R. Prasanna**.

4. "Astrophysics as a Testing Ground for Particle Physics Models", at the Golden Jubilee Meeting on Particle Physics and Gravitation, PRL., Ahmedabad, December 10-14, 1996, by **S. Mohanty**.

Atomic and Molecular Physics

5. "Electron and Positron Impact Excitation of Hydrogen at Intermediate Energies in a VPS-type Multiple Scattering Model", at XI National Conference on Atomic and Molecular Physics, Indian Institute of Technology, Madras, December 17-20, 1996, by **D.P. Dewangan** and S. Chakrabarti.

6. "Closured Second Born Amplitudes for Arbitrary Transitions", at XI National Conference on Atomic and Molecular Physics, Indian Institute of Technology, Madras, December 17-20, 1996, by **D.P. Dewangan** and S. Chakrabarti.

High Energy Physics

7. "Neutrino Physics", at the International Workshop on Fundamental Particles and Quark Matter, Tata Institute of Fundamental Research, ***Bombay, India,*** August 27-31, 1996, by **A.S. Joshipura**.

8. "Neutrino Astroparticle Physics", at the International Conference SUJAYATA in Theoretical Physics, Tata Institute of Fundamental Research, ***Bombay, India,*** September 2-7, 1996, by **A.S. Joshipura**.

9. "R Parity Breaking and Structure of Neutrino Masses and Mixings", at the Trieste Conference on Quarks and Leptons, International Centre for Theoretical Physics, ***Trieste, Italy,*** October 7-11, 1996, by **A.S. Joshipura**.

10. "New Physics at e^+e^- Colliders", at the Golden Jubilee Meeting on Particle Physics and Gravitation, PRL, Ahmedabad, December 10-14, 1996, by **S.D. Rindani**.

11. "New Physics at e^+e^- Colliders", at the XII DAE Symposium on High Energy Physics, Guwahati, December 25, 1996-January 1, 1997, by **S.D. Rindani**.

Nuclear Physics

12. "Group Theoretical Models for Nuclear Structure", Course of Lectures at the SERC School on Physics of Nuclear Structure, Panthanivas, Puri, November 18 - December 7, 1996, by **V.K.B. Kota**.

13. "Shell Model in Large Spaces and Statistical Spectroscopy", at the DAE Nuclear Physics Symposium, G.B. Pant University, Pantnagar, December 20-24, 1996, by **V.K.B. Kota**.

14. "Group Theoretical Aspects of and Open Problems in U(18), U((6) ⊗ U(20) and U(7) Boson and Boson-Fermion Symmetry Schemes", at the International Workshop on Special Functions and Differential Equations, Institute of Mathematical Sciences, **Madras, India,** January 13-24, 1997, by **V.K.B. Kota**.

15. "Dynamical Symmetries for Proton Rich Nuclei in an Isospin Invariant IBM", at the IVth National Workshop on Nuclear Structure Physics, Panthanivas, Puri, March 11-14, 1997, by **V.K.B. Kota**.

Plasma Physics

16. "MHD Phenomena in Dusty Plasmas", at the International Conference on the Physics of Dusty Plasmas, ***Goa, India,*** October 21-25, 1996, by **N.N. Rao**.

17. "Integrability of Coupled Nonlinear Waves in Plasmas", at XI .PSSI National Symposium on Plasma Science and Technology, Barkatullah University,

Bhopal, October 28-31, 1996, by **N.N. Rao**.

18. "Nonlinear Dynamics of Hamiltonian Systems", (a course of **two** lectures) in Refresher Course in Physics, Sardar Patel University, Vallabh Vidyanagar, November 25-December 14, 1996, by **N.N. Rao**.
19. "Adiabatic Invariants in Physics", (a course of **four** lectures) in Refresher Course in Physics, Goa University, Goa, January 16-19, 1997, by **N.N. Rao**.

Non-linear Dynamics and Computational Physics

20. "Chaos, Bifurcation and Exponentially Localized Eigenstates in Smooth Hamiltonian Systems", at the Workshop on Recent Developments in Chaotic Dynamics, Centre for Nonlinear Dynamics, Bharathidasan University, Tiruchirapalli, December 9-13, 1996, by **V.B. Sheorey.**
21. "Computation and Visualization of Highly Excited States of Chaotic Quantum Systems", at the XI National Conference on Atomic and Molecular Physics, Indian Institute of Technology, Madras, December 17-20, 1996, by **V.B. Sheorey**.
22. "Climate Modelling for IGBP Related Studies", at the Second Workshop on ISRO-GBP Results, Indian Space Research Organisation, Bangalore, August 1-2, 1996, by **S.V. Kasture**.

Laser Physics and Quantum Optics

23. "Manipulation of Atoms by EM Fields" at TIFR Golden Jubilee Symposium on Theoretical Physics, Bombay, September 2-7, 1996, by **G.S. Agarwal.**
24. "Coherence from Dissipative Systems" at TIFR Golden Jubilee Workshop on Foundations of Quantum Theory, September, 1996, by **G.S. Agarwal.**
25. "Laboratory-Manipulated Higher Order Poles of S-Matrix and Line Shapes", at International Conference on Quantum Optics, ***Hong Kong,*** January 3-6, 1997, by **G.S. Agarwal.**
26. "Microscopic Models for Correlation Effects in Optical Physics" at Progress In Electromagnetics Research Symposium, ***Hong Kong,*** January 6-9, 1997, by **G.S. Agarwal.**
27. "A Perspective of Near Field Optics - Panel Discussion" at Progress In Electromagnetics Research Symposium, ***Hong Kong,*** January 6-9, 1997, by **G.S. Agarwal.**
28. "Physics and Applications of Man-Made Quantum Interferences" at National Laser Symposium, Indore, February 6-8, 1997, by **G.S. Agarwal.**
29. "SU(1,1) Coherent States" at the International Colloquium on Group Theory, ***Goslar, Germany,*** July 1996, by **G.S. Agarwal.**
30. (a) "Sub-natural Linewidth Spectroscopy and Quantum Noise Quenching - I",

    (b) "Sub-natural Linewidth Spectroscopy and Quantum Noise Quenching - II" and

    (c) "Giant Nonlinear Optics",

    A series of **three** lectures at the Winter College on Quantum Optics, ICTP, ***Italy,*** March 1997, by **G.S. Agarwal.**
31. "Control of Optical Properties of Matter", a Series of **four** lectures at the SERC School of DST on Nonlinear Optics and Laser Spectroscopy held at IIT Delhi, March 1997, by **G.S. Agarwal.**
32. "CAT States in Quantum Physics" at International Workshop on Seventy Years of Schrödinger Wave Mechanics, ***New Delhi, India,*** 28-30 December 1996, by **G.S. Agarwal.**
33. "Generic Nonlinearities and Cat-like States" at International Workshop on Schrödinger Cats, ***New Delhi, India,*** December, 1996, by **J. Banerji** and G.S. Agarwal.
34. "Pattern Formation in Nonlinear Optics", a Series of **four** lectures at the SERC School of DST on Nonlinear Optics and Laser Spectroscopy at IIT Delhi, March 1997, by **J. Banerji.**

Planetary Atmospheres and Aeronomy

35. Series of **three** lectures on:

a. Tropospheric Chemistry.

b. Tropospheric Chemistry in the Polar Region.

c. Ozone Chemistry in the Equatorial Region at the

Third SERC School on Chemistry of Earth's Atmospheric Environment, National Physical Laboratory, New Delhi, April 2-26, 1996 by **Shyam Lal.**

36. Series of **four** lectures on:

a. Radiation and the Atmosphere.
b. General Atmosphere (Chemistry-ions)
c.. Middle Atmosphere (Chemistry-ions)
d. Lower Ionospheric Chemistry at SERC School, National Physical Laboratory, New Delhi, April 2-30, 1996 by **D. K. Chakrabarty.**

37. "Mesopause Scenario on Doubling of CO_2" at the COSPAR Symposium, ***Birmingham, UK,*** July 1996 by **D. K. Chakrabarty.**

38. "Diurnal and Seasonal Variation of D-region Electron Density at Low Latitude", 31st COSPAR Assembly, ***Birmingham, UK,*** July 1996, by **S. P. Gupta.**

39. "Indo-US Results on Aerosol-radiative Forcing from Sagar Kanya Cruise 109" at the INDOEX National Workshop at National Physical Laboratory, New Delhi, August 19-21, 1996 by **A. Jayaraman.**

40. "Aerosol-Radiative Forcing" at the INDOEX International Workshop at Laboratoire de Meteorologie Dynamique, ***Paris,*** September 9-11, 1996 by **A. Jayaraman.**

41. "F-region Irregularities" at the Workshop on Equatorial Aeronomy at VSSC., Thiruvananthapuram, September 14, 1996 by **R. Sekar.**

42. "Ionosphere-Thermosphere Interaction" at the Workshop on Equatorial Aeronomy at VSSC., Thiruvananthapuram, September 14, 1996 by **R. Sridharan.**

43. "Radio Beacon Studies at PRL", at the Symposium on 35 Years of Radio Beacon Studies, NPL, New Delhi, December 1996 by **H. Chandra.**

44. "Groundbased Absorption Studies of Trace Gases" at the International Workshop on Perspective in Atmospheric Chemistry at Physical Research Laboratory, Ahmedabad, December 26-27 1996, by **D. K. Chakrabarty.**

45. "Aerosol Radiation Interactions" at the Perspectives in Atmospheric Chemistry Workshop at Physical Research Laboratory, Ahmedabad, 26-27 December 26-27 1996 by **A. Jayaraman.**

46. "Climatological Aspects of Aerosols with Particular Reference to Aerosols Found over the Arabian Sea" at the Indian Aerosol Science and Technology Seminar at BARC, Bombay, January 22-24, 1997 by **A. Jayaraman.**

47. "Lidar Probing of the Atmosphere", at the National Laser Science Symposium, CAT, Indore, February 1997 by **H. Chandra.**

Earth Sciences and Solar System Studies

Oceanography and Climate Studies

48. "Environmental Radionuclides and Particle Dynamics in the Ocean Water Column" at the International Symposium on Geology and Geophysics of the Indian Ocean, NIO, ***Goa, India,*** October 21-25, 1996 by **S. Krishnaswami.**

49. "Proxy Palaeoclimatic Records in India" at the Indo-Brazilian Joint Workshop on Climate Research, Pune, India, December 9-13, 1996 by **R. Ramesh.**

50. "Late Quaternary Holocene Palaeoenvironmental Record of Thar Desert, India" at the International Workshop on Water, Environment and Society in Times of Climatic Changes, ***Sede Boker, Israel,*** July 7-9, 1996 by **A.K. Singhvi.**

51. "Experimental Evidence of Mid-term Fading of Loess and Possible Mechanism for the Thermoluminescence Age under Estimation" at the National Seminar on Luminescence Dating, ***Freiberg, Germany,*** October 18-20, 1996 by **A.K. Singhvi.**

Solar System and Geochronology

52. "Physical, Chemical and Biological Changes at Geological Boundaries : Causes, Consequences and Clues based on the Study of Indian Sections", Golden Jubilee Conference on Physical and Biological Changes Across the Major Geological Boundaries, Birbal Sahni Institute of Palaeobotany, Lucknow, November 15-17, 1996 by **Bhandari, N.**

53. a. Records of Solar Activity in Planetary Objects.
    b. Paleoactivity of the Sun : Meteoritic Perspective.
    c. The Sun through Time : The Lunar and Planetary Perspective

were presented at the Enrico Fermi - International School of Physics Course CXXXIII on Past and Present Variability of the Solar-Terrestrial System : Measurements, Data Analysis and Theoretical Models held at ***Varenna,*** June 25 - July 5, 1996 organised by Societa Italiana DI FISICA (The Italian Physical Society) by **N. Bhandari**.

Electronics Laboratory

54. "Optimization in Surgery", Gujarat State Surgeons Association (GUSSACON'96), 23rd Annual Conference at Gandhinagar, 23-24 November, 1996, by **H. S. Mazumdar**.

55. "Man Machine Interface", National Hypnosis and Psychosomatic Medicine, Ahmedabad, 1996, by **H. S. Mazumdar**.

CONTRIBUTED PAPERS

Astronomy and Astrophysics

1. "Observational Programs of USO", at PRL Golden Jubilee Workshop on Solar Physics in India during the Next Solar Maximum and Beyond, October 7-10, 1996, USO, Udaipur by A. Ambastha.

2. "Implications of Vector Magnetic Fields for Solar Flares" at PRL Golden Jubilee Workshop on Solar Physics in India during the Next Solar Maximum and Beyond, October 7-10, 1996, USO, Udaipur by A. Ambastha.

3. "High Angular Resolution Studies of Stars and Circumstellar Matter from Gurushikhar Observatory" at Udaipur Solar Observatory during PRL Golden Jubilee Workshop October 7-10 1996 by T. Chandrasekhar.

4. "Microvariability in Blazars", Sixth UN/ESA Workshop on Basic Space Science : Ground Based and Space Borne Astronomy at ***Germany***, September 1996 by M.R.Deshpande.

5. "Near Infrared Observations in Solar Atmosphere" at PRL Golden Jubilee Workshop on Solar Physics in India during the Next Solar Maximum and Beyond. October 7-10, 1996, USO Udaipur by Debi Prasad C.

6. "A PC-based Controller for Solar Eclipse Polarimeter". at PRL Golden Jubilee Workshop on Solar Physics in India during the Next Solar Maximum and Beyond, October 7-10, 1996, USO, Udaipur by S.K. Gupta.

7. "A High-Voltage Power Supply for USO Solar Videomagnetograph", at PRL Golden Jubilee Workshop on Solar Physics in India during the Next Solar Maximum and Beyond, October 7-10, 1996, USO, Udaipur by S.K. Gupta.

8. "The Solar Transient Phenomena and Geomagnetic Activity" at PRL Golden Jubilee Workshop on Solar Physics in India during the Next Solar Maximum and Beyond, October 7-10, 1996, USO, Udaipur by Rajmal Jain.

9. "Solar Video Magnetograph at USO", at PRL Golden Jubilee Workshop on Solar Physics in India during the Next Solar Maximum and Beyond, October 7-10, 1996, USO, Udaipur by Shibu K. Mathew.

10. "The Effect of Opacity Modifications on Solar Oscillations" at Annual GONG 96 meeting, ***Madison, USA,*** June 13-15, 1996 by S.C. Tripathy.

11. "Seismic Probing of the Solar Interior using GONG Frequencies" at Annual GONG 96 meeting, ***Madison, USA,*** June 13-15, 1996 by S.C.Tripathy.

12. "Helioseismic Determination of Opacity Corrections" at IAU Symposium No.181 : Sounding Solar and Stellar Interiors, ***Nice, France,*** September 30- October 3, 1996 by S.C. Tripathy.

13. "Seismic Investigation of the Solar Structure using GONG Frequencies" at IAU Symposium No. 181: Sounding Solar and Stellar Interiors, ***Nice, France,*** September 30-October 3, 1996 by S.C. Tripathy.

14. "Testing the Helioseismic Determination of Opacity Correction" at PRL Golden Jubilee Workshop on Solar Physics in India during the Next Solar Maximum and Beyond, October 7-10, 1996, USO, Udaipur by S.C.Tripathy .

15. "Meterwave Solar Bursts" STPW 1996, ***Hiraiso, Japan,*** January 1996 by Hari Om Vats.

16. "Parameters of Interplanetary Medium" ,PRL Golden Jubilee Workshop at Udaipur, October 7-10, 1996 by Hari Om Vats.

17. "Solar Plasma Acceleration in the Corona", PRL Golden Jubilee Workshop at Udaipur, October 7-10, 1996 by Hari Om Vats.

18. "Solar Wind : Structure and Dynamics", PRL Golden Jubilee Workshop at Udaipur, October 7-10, 1996 by Hari Om Vats.

19. "VLBI in India and International Collaboration", Technical workshop for APT and APSG 1996 at ***Kashima, Japan,*** December 10-13, 1996 by Hari Om Vats.

Theoretical Physics

Non-linear Dynamics and Computational Physics

20. "Study of EEG Signals using Non-linear Dynamics and ANN", at the International Conference on Cognitive Systems, New Delhi, December 13-15, 1996, by D.R. Kulkarni, J.C. Parikh and R. Pratap.

21. "Simulation of Madden and Julian Oscillations in an Aqua Planet Model", at the National Symposium on Monsoon, Climate and Agriculture (TROPMET-97), Indian Institute of Science, Bangalore, February 10-14, 1997, by S.V. Kasture.

22. "Particle Simulation of Collective Thermalisation in Quark Gluon Plasma", at the Workshop on Quantum Chromodynamics: Collision, Confinement and Chaos, **Paris**, June 3-8, 1996 by S. Sengupta, P.K. Kaw and J.C. Parikh.

Plasma Physics

23. "Charging of Dust Grains by a Flowing Plasma", at the International Conference on the Physics of Dusty Plasmas, **Goa, India,** 21-25 October 1996, by S.B.Banerjee, R.K. Varma and A.M. Punithavelu.

Laser Physics and Quantum Optics

24. "Sub-Doppler Resolution in Inhomogeneously Broadened Media using Intense Control Fields", CLEO Meeting, ***Anaheim, California,*** June 2-7, 1996, G. Vemuri, B.D. Nageswara Rao and G.S. Agarwal.

25. "Coherence Induced Effects in Pulse-Pair Propagation Through Absorbing Media", CLEO Meeting, ***Anaheim, California,*** June 2-7, 1996, G. Vemuri, K.V. Vasavada and G.S. Agarwal.

26. "Soliton Amplifiers", International Conference on Quantum Optics, ***Hong Kong,*** January 3-6, 1997, G. Vemuri, K.V. Vasavada and G.S. Agarwal.

27. "Gain in V-system with a Bichromatic Drive", International Conference on Quantum Optics, ***Hong Kong,*** January 3-6; 1997, S. Arun Kumar, G.S. Agarwal and T.W. Mossberg.

28. "Phase Conjugation of Weak Continuous-Wave Optical Signals", Annual Meeting of Optical Society of America, ***Rochester, New York,*** October 1996, M.Y. Lanzerotti, R.W. Schirmer, A.L. Gaeta and G.S. Agarwal.

29. "Modelling Mode Hopping in Optical Parametric Oscillators", Annual Meeting of Optical Society of America, ***Rochester, New York,*** October 1996, G.S. Agarwal and S. Dutta Gupta.

30. "Correlation-induced Spectral Changes and Energy Conservation", Annual Meeting of Optical Society of America, ***Rochester, New York,*** October 1996, E. Wolf and G.S. Agarwal.

31. "Laser Beam Filamentation Initiated by Quantum Fluctuations", Annual Meeting of Optical Society of America, ***Rochester, New York,*** October 1996, E. M. Nagasako, Robert W. Boyd and G.S. Agarwal.

32. "Cross-section Theorem for Scattering on Random Media", Annual Meeting of Optical Society of America, ***Rochester, New York,*** October 1996, P. Scott Carney, G.S. Agarwal, P. Scott Carney and E. Wolf.

33. "Injection Locking in Distributed Feedback Diode Lasers", National Laser Symposium, Indore, February 6-8, 1997, S Sivaprakasam and Ranjit Singh.

34. "Coherent Optical Interference Effects in Diode Lasers with Optical Feedback", National Laser Symposium, Indore, February 6-8, 1997, P Anantha Lakshmi, Ranita Saha and Ranjit Singh.

35. "Laser Resonators with Self-imaging Waveguides", CLEO/Europe Conference held at ***Hamburg***, September, 1996, J. Banerji, A. R. Davies and R. M. Jenkins.

36. "Laser Resonators with Self-imaging Waveguides", National Laser Symposium, Indore, February 6-8, 1997, J. Banerji, A. R. Davies and R. M. Jenkins.

37. "Quantum Evolution of Classical Dressed Mode in Nonlinear Optical Interaction", National Laser Symposium, Indore, February 6-8, 1997, J.Banerji and G. S. Agarwal.

38. "Can Homodyne Spectrum Yield Redistribution of Radiation?", National Laser Symposium, Indore, February 6-8, 1997, R.P. Singh, G.S. Agarwal and T.W. Mossberg.

39. "Probe Propagation in a Ladder System and its Noise Characteristics", National Laser Symposium, Indore, February 6-8, 1997, S. Arun Kumar.

40. "Quantum Interference Effects in Trapped Population of Atoms Driven by Phase Modulated Fields", National Laser Symposium, Indore, February 6-8, 1997, W. Harshawardhan.

Planetary Atmospheres and Aeronomy

41. "Longterm Changes in Ionospheric Parameters over Ahmedabad" at the 31st Scientific Assembly of COSPAR, ***Birmingham, UK***, July 14-21, 1996, by H. Chandra, G.D. Vyas and S. Sharma.

42. "Ionospheric Effects of the Total Solar Eclipse of 24th October 1995 over Ahmedabad", at the 31st Scientific Assembly of COSPAR, ***Birmingham, UK***, July 14-21, 1996, by G.D. Vyas, H. Chandra, and S. Sharma.

43. "Rayleigh Lidar Studies of Gravity Wave Features over Aberystwyth", at the 31st Scientific Assembly of COSPAR, ***Birmingham, UK***, July 14-21, 1996, by H. Chandra and S. Ramaswami.

44. "Lidar Studies at a Tropical Site over Ahmedabad", at the 31st Scientific Assembly of COSPAR, ***Birmingham, UK***, July 14-21, 1996, by H. Chandra, A. Jayaraman, B.H. Subbaraya, Y.B. Acharya, S. Ramaswami and S. Ramachandran.

45. "On Unequal Distribution of Positive and Negative Ions in the Upper Stratosphere" at COSPAR Symposium, ***Birmingham, UK***, July 14-21 1996 by D. K. Chakrabarty.

46. "Features of E-region Irregularities at the Magnetic Equator and its Vicinity", 31st COSPAR Assembly, ***Birmingham, UK***, July 14-21 1996 by S. P. Gupta.

47. "Role of Lightning above Thundercloud in Producing Ionisation in Stratosphere", 31st COSPAR Assembly, ***Birmingham, UK***, July 14-21 1996 by S. P. Gupta.

48. "Vertical Distribution of CFCs, HCFCs and other Trace Gases over the Tropics obtained from ISRO-GBP Cryosampler Measurements and Studies on Atmospheric Chemistry" at the Second Workshop on ISRO-GBP Results, Bangalore, August 2-4, 1996 by P.K. Patra, Shyam Lal, P. Rajaratnam, Y.B. Acharya and B.H. Subbaraya.

49. "Variabilities of Ozone and its Precursor Gases in Different Environments in the Indian Region" at the Second Workshop on ISRO-GBP Results, Bangalore, August 2-4, 1996 by Shyam Lal, B.H. Subbaraya, S. Venkataramani and K.S. Modh.

50. "Measurements of Daytime Auroral Emissions from Maitri, the Indian Station in Antarctica", at the Scientific Committee for Antarctica Research (SCAR) meetings at ***Cambridge, UK***, August 4-11, 1996 by R. Sridharan.

51. "National Report on the Solar-Terrestrial Research from Antarctica", at the Scientific Committee for Antarctica Research (SCAR) meetings at ***Cambridge, UK***, August 4-11, 1996 by R. Sridharan.

52. "Ionospheric Effects of the Solar Eclipse of 24 October 1995 over Ahmedabad", at the Conference of Solar Physics in India during the Next Solar Maximum and Beyond, USO, Udaipur, October 7-10 1996, by H. Chandra, G. D. Vyas and S. Sharma.

53. "Role of Solar Wind Interaction on Venus and Mars" at PRL Golden Jubilee Workshop on Solar Physics in India during the Next Solar Maximum and Beyond, Udaipur Solar Observatory, Udaipur, October 7-10, 1996 by S.A. Haider.

54. "Role of Thunderstorm in Global Electric Circuit", Special IAGA Symposium, ***Bombay, India***, November 18-20, 1996 by S. P. Gupta.

55. "Total Electron Scattering Cross Sections for CO_2 at Low Electron Energies" at XI National Conference on Atomic and Molecular Physics, Chennai, December 17-20, 1996 by P. Rawat, K.P. Subramanian and Vijay Kumar.

56. "Fluorescence and Radiative Life Time Studies on NO_2" at XI National Conference on Atomic and Molecular Physics, Chennai, December 17-20, 1996 by V. Sivakumaran, K.P. Subramanian and Vijay Kumar.

57. "Temperature Dependence of Photoabsorption Cross Section of SO_2 at 188-220 nm" at XI National Conference on Atomic and Molecular Physics, Chennai, December 17-20, 1996 by V. Prahlad and Vijay Kumar.

58. "Spectroscopic Studies of Laser Produced Plasmas" at XI National Conference on Atomic and Molecular Physics, Chennai, December 17-20, 1996 by I.A. Prajapati, K.P. Subramanian and Vijay Kumar.

59. "Air-sea Interaction: Connecting the Ocean and Atmosphere", Workshop on Perspectives in Atmospheric Chemistry, Ahmedabad, December 26-27, 1996 by P.K. Patra.

60. "Distribution of Trace Gases in the Tropics", Workshop on Perspectives in Atmospheric Chemistry, Ahmedabad, December 26-27, 1996 by Shyam Lal.

61. "Recent Trends in Low Level Ozone over India" INDOEX International Workshop, NPL, Delhi, January 3-6, 1997 by Shyam Lal.

62. "Nitrous Oxide and Methane Emissions from Arabian Sea - A Season Based Assessment", ISRO-GBP Symposium, Bhubaneswar, January 17-19, 1997 by P.K. Patra, Shyam Lal and S. Venkataramani.

63. "Growth Rates and Role of New CFC Substitutes on Ozone Chemistry in the Lower Atmosphere", ISRO-GBP Symposium, Bhubaneswar, January 17-19, 1997 by Shyam Lal, P.K. Patra and P.J. Crutzen.

64. "On Short-period Fluctuation in Horizontal and Vertical Wind Velocities over Tirupati", at the Third User Scientists Workshop on MST Radar Results, Tirupati, February 1997, by D. K. Chakrabarty.

Earth Sciences and Solar System Studies

Oceanography and Climate Studies

65. "Palaeoclimatic Studies using Continental Margin Sediments of Western India" at the Geological Society of India Annual Convention, Mangalore University, Mangalore, October 15-18, 1996 by R. Agnihotri, M. Dixit, K. Dutta, C. Sharma and B.L.K. Somayajulu.

66. "Geochronological and Geochemical Studies of the Western Continental Margins of India" at the IGBP National Symposium on Changes in Global Climate due to Natural and Human Activities, Regional Research Laboratory, Bhubaneswar, January 15-17, 1997 by R. Agnihotri, M. Dixit, K. Dutta and B.L.K. Somayajulu.

67. "Calcareous Nodules and Stromatolites from Gondwana Basin of Eastern India" at the 30th International Geological Congress, ***Beijing***, August 1996 by S.K. Bhattacharya, P. Ghosh, A. Chakrabarti and K.L.Pandya.

68. "Atmospheric Carbondioxide and Other Trace Gases in a Tropical Indian Station" at the Co-ordinated Research Programme of IAEA on Isotope-aided Studies of Atmospheric Carbondioxide and Other Green House Gases-Phase 2, ***Vienna***, October 28-31, 1996 by S.K. Bhattacharya, R.A. Jani, D.V. Borole, R.J. Francey and K. Masarie.

69. "An Explanation of the Anomalous Isotopic Composition in Stratospheric Carbondioxde" at the Co-ordinated Research Programme of IAEA on Isotope-aided Studies of Atmospheric Carbondioxide and Other Green House Gases-Phase 2, ***Vienna***, October 28-31, 1996 by S.K. Bhattacharya, R.J. Francey, C.E. Allison, U. Schmidt and T. Gamo.

70. "Talchir Deposits in the Gondwana Basins of India and their Palaeoclimatic Significance" in Proc. of VII

National Symposium on Mass Spectrometry, Gwalior, November 26-28, 1996 by P. Ghosh, S.K. Bhattacharya and A. Chakrabarti.

71. "Sr Isotopes in the Ocean : The Himalayan Connection" at the International Symposium on Geology and Geophysics of the Indian Ocean, NIO, ***Goa, India***, October 21-25, 1996 by S. Krishnaswami.

72. "First AMS in India: Proposal and Programme" at the VIIth International Conference on Accelerator Mass Spectrometry, Tuscon, ***Arizona, USA***, May 20-24, 1996 by D.P. Mahapatra, B.L.K. Somayajulu and K. Gopalan.

73. "Oxygen Isotopic Variations in Speleothem from Jammu: Climatic Implications" at the VIIth National Symposium on Mass Spectrometry, Gwalior, November 26-28, 1996 by J.T. Padia and K.K. Sharma.

74. "Stable Isotope Study of Water Bodies in Himalayan and Trans-Himalayan (Kashmir) Region" at the VIIth National Symposium on Mass Spectrometry, Gwalior, November 26-28, 1996 by J.T. Padia, K. Pande, R. Ramesh and K.K. Sharma.

75. "Stable Carbon and Oxygen Isotopes in Hydrothermally Altered Carbonatites, Amba Dongar, Gujarat" at the VIIth National Symposium on Mass Spectrometry, Gwalior, November 26-28, 1996 by J. S. Ray and R. Ramesh.

76. "Radionuclide Scavenging in the Surface Layer of the Arabian Sea and its Relationship to Particle Export" at the Geological Society of India Annual Convention, Mangalore University, Mangalore, October 15-18, 1996 by M.M. Sarin.

77. "U-Th Series Nuclides Settling Fluxes in the Bay of Bengal" at the International Symposium on Geology and Geophysics of the Indian Ocean, National Institute of Oceanography, **Goa, India**, October 21-25, 1996 by M.M. Sarin, S. Krishnaswami, R.R. Nair, V. Ramaswamy and V. Ittekkot.

78. "^{234}Th Scavenging and Particle Export Fluxes from the Upper 100m of the Arabian Sea" at the National Symposium on Changes in Global Climate due to Natural and Human Activities, Regional Research Laboratory, Bhubaneswar, January 15-17, 1996 by M.M. Sarin and R. Rengarajan.

79. "^{210}Po and ^{210}Pb in the Ocean Water Profiles of the Central-Eastern Arabian Sea" at the National Symposium on Changes in Global Climate due to Natural and Human Activities, Regional Research Laboratory, Bhubaneswar, January 15-17, 1996 by M.M. Sarin and R. Rengarajan.

80. "Atmospheric Input of Nitrate and ^{210}Pb to the Central-Eastern Arabian Sea" at the National Symposium on Changes in Global Climate due to Natural and Human Activities, Regional Research Laboratory, Bhubaneswar, January 15-17, 1997 by M.M. Sarin, R. Rengarajan and S. Krishnaswami.

81. "Ra isotopes in the Adjacent Seas of India" at the International Atomic Energy Agency Seminar on Use of Isotope Techniques in Marine Environmental Studies, ***Athens, Greece***, November 11-22, 1996 by B.L.K. Somayajulu.

82. "Dating Archaeological Material" at the Indian Human Heritage Symposium, Indian National Science Academy, New Delhi, December 31, 1996 to January 1, 1997 by B.L.K. Somayajulu.

83. "Recent $CaCO_3$ Deposition on the Western Continental Margins of India" at the International Symposium on Geology and Geophysics of the Indian Ocean, National Institute of Oceanography, Goa, October 21-25, 1996 by B.L.K. Somayajulu and Charu Sharma,

84. "Sr Isotopic and Chemical Composition of Carbonates from the Himalaya: Implications to Silicate versus Carbonate Weathering and Climate Change" at the VIIth National Symposium on Mass Spectrometry , Gwaliŏr, November 26-28, 1996 by Sunil K Singh, J.R. Trivedi, Kanchan Pande and S. Krishnaswami.

Solar System and Geochronology

85. "Multiple Ir-rich Layers in the Anjar K/T Section" at the 59th Meteoritical Society Meeting, ***Berlin, Germany***, July 22-26, 1996 by N. Bhandari, P. N. Shukla, A. D. Shukla, and Z. G. Ghevariya.

86. "Short-lived Nuclides in the Early Solar System : The

Possible Role of an Active Early Sun" at the 59th Meteoritical Society Meeting, Humboldt Univ., ***Berlin, Germany***, July 22-26, 1996 by J.N. Goswami, K.K. Marhas and S. Sahijpal.

87. "Production of Short-lived Nuclides by Solar Energetic Particles in the Early Solar System" at the 28th Lunar Planet Sci., ***Houston, USA***, March 17-21, 1997 by J.N. Goswami, K.K. Marhas and S. Sahijpal.

88. "Potassium and Mg Isotopic Studies of CM Hibonites" at the 59th Meteoritical Society Meeting, Humboldt Univ., ***Berlin, Germany***, July 22-26, 1996 by J.N.Goswami, S. Sahijpal, A.M. Davis, L. Grossman and R.S. Lewis.

89. "Martian Atmospheric Component in the Antarctic Meteorite ALH 84001" at the 8th National Symposium on Mass Spectrometry, Gwalior, November 26-28, 1996 by R.K. Mohapatra, and S.V.S. Murty.

90. "Nitrogen Components in the Dhajala Meteorite" at the 59th Meteoritical Society Meeting, ***Berlin, Germany***, July 22-26, 1996 by S.V.S. Murty.

91. "Search for Extinct ^{36}Cl in a Halogen Rich Chondrule of Allende" at the 59th Meteoritical Society Meeting, ***Berlin, Germany***, July 22-26, 1996 by S.V.S.Murty and G.J. Wasserberg.

92. "Search for Extinct ^{36}Cl in Primitive Meteorites" at the Working Group Meeting on Meteorite Research by German Speaking Nations. ***Ringberg, Germany***, June 3-5, 1996, by S.V.S.Murty.

93. "Geochemical Characterisation of K/T Boundary Sediments at Anjar, India", at the Golden Jubilee Conference on Physical and Biological Changes Across the Major Geological Boundaries, Birbal Sahni Institute of Palaeobotany, Lucknow, November 15-17, 1996 by P.N. Shukla, A.D. Shukla and N. Bhandari.

94. "Source(s) of Short-lived Nuclides in the Early Solar system : Constraint from Correlated Observation of ^{41}Ca on Mass Spectrometry" at the 8th National Symposium on Mass Spectrometry, Gwalior, November 26-28, 1996 by S. Sahijpal and J.N. Goswami.

95. "Cosmic Ray Produced Nitrogen in Meteorites : An Experimental Approach" at the 8th National Symposium on Mass Spectrometry, Gwalior, November 26-28, 1996 by V.K. Rai and S.V.S. Murty.

96. "Sr Isotopes of Amba Dongar Alkaline Rocks : Evidence for Liquid Immiscibility and Wall-rock Assimilation", National Symposium on Mass Spectrometry, Gwalior, November 26-28, pp. 390-393, 1996 by J.S. Ray and J.R. Trivedi.

97. "Rb-Sr age of Kepsar-Thayeli Gabroic Body, Garhwal Himalaya : Implications for Paleo-Proterozoic Basic-acidic Bimodal Magnetism in Himalaya", National Symposium on Mass Spectrometry, Gwalior, November 26-28, 1996 by T. Ahmad, J.R. Trivedi and P.K. Mukherjee.

98. "Zircon Geochronology of the Singhbhum-Orissa Craton, Eastern India : An Ion Microprobe Study", at the 8th National Symposium on Mass Spectrometry, Gwalior, November 26-28, by J.N. Goswami, S. Mishra, M.P. Deomurari, M. Wiedenbeck, S.L. Ray and A.K. Saha.

Library

99. "Information Technology for Sharing Library Resources", at the Fourth National Convention on IT Applications in Academic Libraries in India, Patiala,March 6-8, by Rhoda Bharucha.

100. "Accessing Electronic Resources", at the Fourth National Convention on IT Applications in Academic Libraries in India, Patiala, March 6-8, by Rohini Patil and Rhoda Bharucha.

Electronics Laboratory

101. "Crime Detection System using Neural Network" at the International Conference of Forensic Science Laboratories, **Australia**, by H.S. Mazumdar, Leena P. Rawal and D. Nandi Anupama.

Science
at
PRL

The scientific programmes of the Astronomy and Astrophysics division encompass studies of active galactic nuclei, star burst galaxies, stellar evolution, star formation, kinematic studies in planetary nebulae and regions of star formation, high angular studies through lunar occultation, solar physics and comets. This year comet Hale Bopp was studied extensively. Some important scientific achievements are described below.

Variability Study of BL Lac Objects

Polarization observations on OJ287 and Mrk 421 were continued. In addition to polarization observations, OJ 287 was monitored on several nights for detecting short-time scale variations (at a level of 2-3%) in flux in optical region with the new CCD camera. The intraday variability has been detected.

Theoretical synchrotron spectrum in the frequency range 10^{11} - 10^{17} Hz was compared with the observed spectral distribution and upper and lower frequency cut-offs were estimated. These frequencies were used to obtain the theoretical values of variability and magnetic field in the emission region. We obtain a value of 0.93 Gauss for the magnetic field and 5 x 10^7 sec for the cooling time for quiescent continuum spectrum.

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

Unified Scheme of AGNs

A large sample of radio sources, including powerful radio galaxies and quasars, is being studied. The information on radio sizes and redshifts of these sources are being obtained in collaboration with an Italian group of astronomers. The distribution of these properties is being studied to further test the unified scheme of radio galaxies and quasars. The indications are that a simple unified scheme does not fit the observations.

(A.K.Singal)

Radio Source Mapping

A sample of giant radio galaxies and quasars has been observed with the VLA in USA and Westerbork telescope in Netherlands. The calibrated data is being reduced to get detailed 2-dimensional brightness distribution maps of these sources. Multiple hot-spots are seen in atleast one of these giant radio galaxies.

(A.K.Singal)

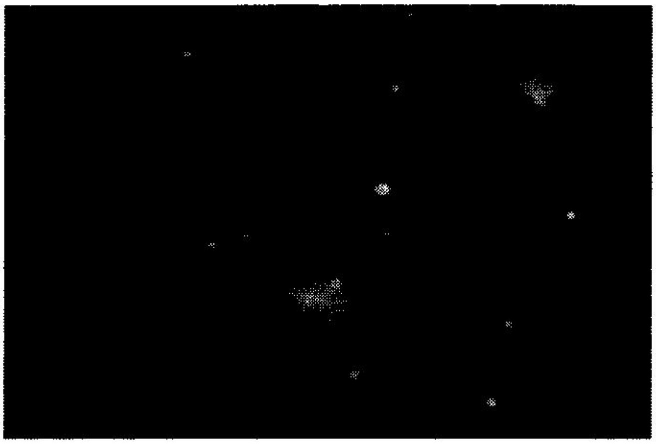


Fig. 1.1 Tidal interaction between the larger spiral galaxy has induced starburst activity in the smaller irregular galaxy Mrk 1134

Starburst Galaxies

Under the ongoing programme of studying starburst galaxies, a sample of about 15 galaxies was observed during this year using the new CCD camera specially developed for this work. All the galaxies in the sample have a redshift of about 0.01, which enables the same spatial resolution. Broad band (UBVRI), and narrow band (Hα) observations were carried out. The sample contains galaxies exhibiting a wide range of morphologies from ellipticals to spirals to completely distorted systems. Most of the galaxies have a bright nucleus - the site of the starburst activity. Some of them show extranuclear activity in either circumnuclear or in discrete hot spots **(Fig.1.1)**.

One of the galaxies, Mrk 332, shows the presence of a distinct ring of star formation around the nucleus. The ring has a diameter of about two kpc. The colors in the ring are much bluer than those in the nuclear region. Another interesting case is of Mrk 87, the nucleus showing a pair of galaxies which shows the presence of a ring around it. Such a ring is usually formed due to interaction with a companion galaxy or due to resonances.

(U.C.Joshi and Aparna Chitre)

Detection of C_2 Origin from Cometary Dust

The knowledge of the origin and formation of various molecules in the inner coma region of comets is extremely important. In comets, C_2 emission bands lie in the visible region of the spectrum and are quite strong. However, the production mechanism of C_2 molecules is not very clear. CO, CO_2 and CH_4 molecules have been considered as the main parent molecules for atomic carbon and other carbon bearing daughter molecules. However, a large discrepancy in the observed and estimated values of the abundances of atomic carbon and carbon bearing molecules in the inner coma region is noticed. The apparition of comet Hyakutake in 1996 provided us an opportunity to address this issue. On March 20, comet Hyakutake was almost at its closest approach to earth providing a unique opportunity to obtain images with very high spatial resolution. Observations were made in two continuum and two emission band filters. This high resolution enabled us, for the first time, to detect a strong correlation between C_2 emission concentration and highly dusty region of the coma. This strong correlation suggests that dust also harbours C_2 which is ejected in short time after the dust is released from the nucleus. From the present study we conclude that the dust ejected from the nucleus of comet is a source of C_2.

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

Near Infrared Observations of Comet Hyakutake (C/1996 B2)

Near Infrared photometric observations were carried out in the preperihelion phase in J, H and K filter bands during the apparition of Comet Hyakutake (C/1996 B2). The effective temperature of the comet was found to be ~ 20% higher than that of a equilibrium fast rotating blackbody at the same heliocentric distance (r). A dust albedo of 0.12 ± 0.2 is derived which is similar to the values for Comet Kohoutek but distinctly higher than the values for Comet Halley. The brightness variation of the scattered flux in the K band follows a $r^{-4.3 \pm 0.3}$ law which is again consistent with a long period comet. It appears, from our limited IR observations that Comet Hyakutake belongs to a class of long period comets like Kohoutek and is different from inner solar system comets including Halley.

In addition to photometric observations of Comet Hyakutake the infrared flux of two bright sources (IRC 30265, m_k=2.0) and (IRC 70123, m_k=1.13) were monitored for several hours in each case, in the K band when they made close approaches to the comet on 23 March 1996 and 25 March 1996 respectively. Neither of the two sources was predicted to be occulted by the cometary nucleus but as they passed through the inner coma, monitoring of the sources in the K band was undertaken to determine limits of optical depth of the inner coma at 2.2 microns. No detectable decrease in the signal strength was noted during either of the encounters. From our observations we derive an upper limit to the optical depth at 2.2 microns at a cometocentric distance of 32000 km as $t_k < 0.014$.

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

Polarimetric Study of Comet Hale-Bopp

Observation of the continuum polarization of the radiation in comets is a powerful method to study the characteristics of the cometary dust grains. We made observations of Comet Hale-Bopp C/1995 01 with the Optical Polarimeter at the Cassegrain focus of the 1.2m telescope at Mt. Abu. The observations were conducted during the months of October, November 1996 and February 1997. The position angle of linear polarization is found to be parallel to the scattering plane during October and November 1996, i.e. the polarization is negative. It is found to be positive during the later observations.

The observations made during February and later show increase in degree of polarization with increase in phase angle in all three continuum bands. The wavelength dependence of the polarization at various phase angles is shown in figure **(Fig.1.2)**. The polarization in Hale-Bopp exhibits a stronger wavelength dependence than in Halley. In the 3650A band, the nature of the polarization is similar to Halley. The polarization in the 4845A band for phase angles greater than 30° is larger for Hale-Bopp than Halley. This departure in wavelength dependence from Comet Halley suggests that Comet Hale-Bopp contains smaller grains. A theoretical model to

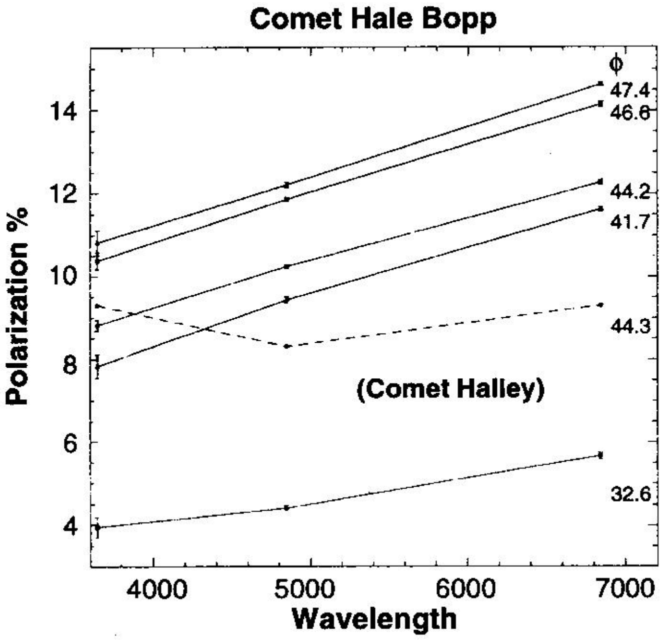


Fig. 1.2 Wavelength dependence of continuum polarisation in Comet Hale-Bopp is shown at different phase angles and is compared with that of Comet Halley. The wavelength dependence is stronger in Comet Hale-Bopp compared to Comet Halley

fit the observed polarization and to determine grain characteristics of the comet is in progress.

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

Kinematic Studies on H II Regions Associated with Star Formation Complexes

New spatially resolved (4") observations of velocity fields were made on the HII region Lagoon Nebula (NGC 6523, M8) using the PRL Imaging Fabry-Perot Spectrometer in [NII] 6583A and [OIII] 5007A emission lines **(Fig.1.3).**

We have found from our [NII] observations on the HII region that there exists a notable expansion of ionized gas around the 07 V type star Herschel 36 (Her 36). The expanding bubble of ionized gas is interacting with the parent molecular cloud creating two large cavities in it. The mouth of one of the cavities is near-perpendicular to the line of sight, while the inner walls of the other cavity are seen face-on by the observer.

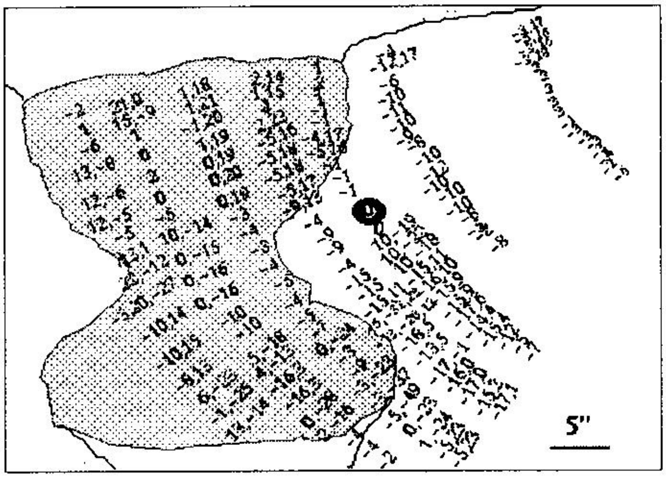


Fig. 1.3 Velocity field as traced out by the [NII] emission line around the ionizing star Her 36 (open circle) and the Hourglass (shaded region) in the Lagoon Nebula, M8. The numbers represent radial (line - of - sight) velocity in km/s taken with respect to Her 36.

Relatively higher velocities of - 30 to - 50 km/s were observed 15" to 20" south of Her 36 signifying the presence of low density regions and a beginning of the champagne flow.

The large line widths observed can be reconciled with a most probable turbulent velocity of 15 km/s and density gradient appropriate for an expanding HII region, evolving with an age of 5×10^4 years.

The observations on the [OIII] velocity field reveal clearly split lines in the southern lobe of the Hourglass region and corroborate the [NII] results. The line widths of [OIII] are smaller than those of [NII].

Recent narrow-band picture taken by the Hubble Space Telescope also reveals a very complex structure in the region of Hourglass and Her 36.

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

Simultaneous X-ray, Ultraviolet and Optical Variations in I Eridani : International Campaign

An international campaign was carried out from ground stations and with ROSAT, ASCA, IUE and Voyager 2 space platforms during a week in February-March

1995 to monitor simultaneous variations in the B2e star l Eridani. PRL had participated in it by contributing simultaneous observations from Mt.Abu on the Hα line using the central-aperture scanning Fabry-Perot spectrometer at the cassegrain focus of the 1.2m telescope.

Possible low level fluctuations in the February-March ROSAT data occurred at the same time as unusual activity in Hα, HeI 6678 A, HeII 1640A, and the CIV doublet. The hydrogen and helium profiles exhibited an emission in the blue half of their profiles lasting for several hours. The CIV lines showed a strong high-velocity Discrete Absorption Component accompanied by unusually strong absorption at lower velocities. The helium line activity suggests that a mass ejection occurred at the base of the wind while the strong CIII (Voyager 2) and CIV (IUE) lines imply that shock interactions occurred in the wind flow.

Within hours of the mild X-ray flux variations found by ROSAT on February 28, the Voyager 2 UVS (980-1300A) observed a "ringing" that decayed over three cycles of 3 hrs duration. The amplitude of these fluctuations decreased rapidly with wavelength and faded to non-detection longward of λ 1300A. It is conjectured that a dense plasma structure over the star's surface is heated and cooled quasi-periodically to produce such flux changes.

The increase in the emission of the Hα line occurred at about the time the FUV ringing started hints that the plasma at the temperature of ~ 50000 K near the star's surface can influence the circumstellar disc at ~ 12 R_* by its increased Lyman continuum flux. This project was executed in collaboration with Myron Smith of GSFC, NASA.

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

Angular Diameters and Effective Temperatures of M Giants from Lunar Occultation Observations in the Infrared

The method of lunar occultations provides important high angular resolution information on stellar sources - the angular diameter of the star, multiplicity in the stellar system, and detection of any circumstellar matter if present. From angular size, knowing the star's total luminosity, it is possible to derive the effective temperature of the star accurately - an important parameter for models of stellar evolution. At PRL, the technique of lunar occultations has been used in the near infrared for the past several years. During this year we report the results of our stellar observations of six M giants (**Table 1**) in the K band (2.2 microns).

Table 1

Source	Sp.Class	S/N	ϕ(mas)	T_{eff}
IRC+20190	M2 III	75	< 2	-----
NSV 1529	M2-M7 III	120	3.3+0.3	3380+160
BQ Ori	M5 III	85	4.2+0.2	3460+100
IRC+10194	M3.3 III	30	4.2+0.5	2760+170
IRC+10024	M2 III	110	3.2+0.2	3650+100
IRC+00198	M2 III	73	< 2	-----

The angular size (f) reported are uniform disk diameters in milliarc seconds (mas). For IRC+10194, we report the first measurement of angular size in the K band. The derived effective temperature of 2760 ± 170 K, is consistent with an earlier measurement in the H band (1.65 microns) but it is too low for an early M giant considered. A photometric variability of atleast 0.1 magnitude has been established but this is still inadequate to account for the lower temperature. Possibility of large star spots on the stellar surface need to be investigated for this source. In case of BQ Ori our results provide the most accurate angular size so far available. In all the six systems investigated, there is no evidence, within experimental limits, of multiplicity or circumstellar material.

(T.Chandrasekhar, N.M.Ashok and Sam Ragland)

Infrared Photometry of Short Period Algol Systems

An infrared monitoring programme of Algol systems is in progress for the last two years. The Algol systems are semi-detached class of binary stars that have undergone

Table 2 : Absolute Dimensions of RZ Cas

Parameter	Primary	Secondary
Mass *	2.21 + 0.26	0.73 + 0.07
Mean Radius *	1.69 + 0.06	1.95 +0.06
Mean Temperature	8720 K	4206 + 28 K
Luminosity *	14.90+ 1.06	1.07 + 0.01
Mean log (g)	4.33 + 0.02	3.72 + 0.01

* In solar Units.

mass reversal. We report here the completed light curves in the near infrared of RZ Cassiopeiae (RZ Cas), a member of the short period Algol group.

RZ Cas was observed from October 1995 to January 1997. The present observations have provided the first light curves in J and K bands. These have been analysed to determine the physical parameters of the system. We find RZ Cas to be a partially eclipsing system with an orbital inclination of 82.13° matching well with the previous estimates based on optical observations. The absolute elements were derived and are given in **Table 2.** The J light curve along with model fit is shown in figure **(Fig.1.4)**. The surprising result emerging from our analysis is the substantially lower temperature, 400 K less than the value found from optical light curves, of the secondary component.

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

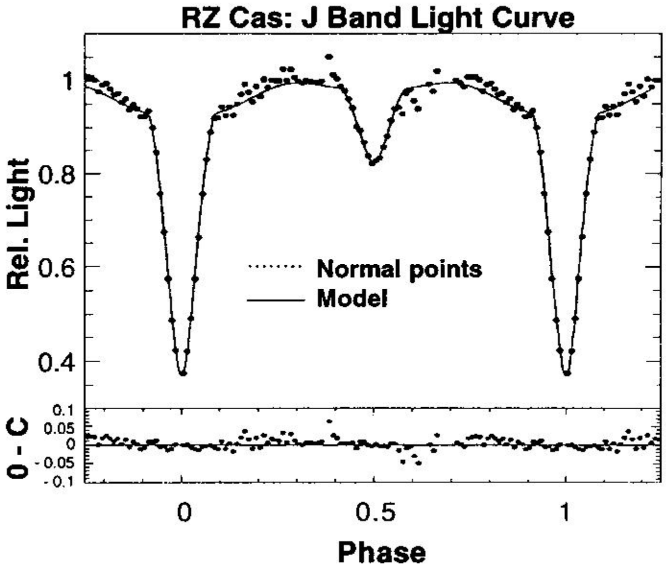


Fig. 1.4 J band light curve RZ Cas, the model fit and the residuals (o-e)

Plasma Disturbances Associated with Solar Bursts : An International Collaboration

Meterwave radiation from Sun has been of great scientific excitement and most interesting events in this branch of solar physics have been the large outbursts lasting from few seconds upto 20 minutes which are usually accompanied with large flares and coronal mass ejections. Two such outbursts are investigated using Hiraiso radio spectrograph (Kashima) and IPS arrays of Rajkot and Thaltej and geomagnetic data. These events occurred on 6 January 1994 and 30 September 1993 and were possibly connected to NOAA/USAF active regions # 7646 and 7590 respectively. It is found that the type II solar bursts are caused by the particle beams having velocities much smaller than those for type III bursts. The plasma density enhancement due to the plasma disturbances associated with these bursts are by a factor of 36 and 16 respectively. From the point of view of terrestrial effects of these solar events, it is clear that the duration of geomagnetic disturbance seems to be related to the plasma density enhancement. This work is in collaboration with Dr.T.Kondo, Kashima Space Research Center, Japan.

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

Rotational Modulation of Microwave Solar Flux

Recent studies have revealed that the microwave radiation from the Sun is responsive to the same conditions that produce magnetically structured radiation at visible and X-ray wavelengths. With this in view, the time series data of 10.7 cms solar flux for solar cycle 22 was processed through auto correlation analysis. Rotational modulation with varying persistence and period was quite evident. The persistence of modulation has no relation with sunspot numbers. Using rotational property, the solar flux was split in two parts i.e. background emission which remains unaffected by solar rotation and the localized emission which produces the observed rotational modulation. Both these parts show a direct relation with the sunspot numbers. The magnitude of localized emission almost diminishes during the period of low sunspot number, whereas background emission remains at 33% level even when no sunspots are present. This gives an indication that microwave solar flux of ~ 60 SFU will be present during a situation like Maunder minimum which appears to be a reality and not an artifact of poor observations.

(Hari Om Vats, M.R.Deshpande and Chhaya R.Shah)

Spectrum of Solar Flux at 2800 MHz

For solar cycle 22 (1985-95), daily values of solar flux at 2800 MHz are arranged in time series and analysed using Cooley-Tuckey method for several lag size e.g. 1000, 1500 and 2000 days in auto covariance and finally spectrum. One example of this spectrum for the frequency range of 0.001 to 0.1 Hz is shown in figure **(Fig.1.5)**. There is a dominant peak at 0.0377 cycle/day or at a period ~ 26.52 days and represents the synodic rotation period of the solar corona. This gives a sidereal rotation period and rate as 24.73 days and 14.56 deg/day respectively. The comparison with other measurements for rotation of solar corona clearly shows that sidereal rotation period by the spectrum analysis of microwave flux is less than all other techniques e.g. coronal green line, coronograph and coronal holes by about 2-7%. This could be due to the fact that different tracers used for measuring solar coronal rotation are representatives of solar corona at different height and most of these variations could be due to differential rotation of solar corona as a function of height.

(Hari Om Vats, Chhaya R.Shah and M.R.Deshpande)

Structure and Dynamics of Solar Wind

The interplanetary scintillation (IPS) observations are used for the determination of structure and dynamics of the solar wind. The parameters of the plasma irregularities of the solar wind are usually derived by investigating the interplanetary scintillations in the light of scattering theories. Upper and lower roll-off spatial frequencies are calculated using diffractive-refractive scattering approach.

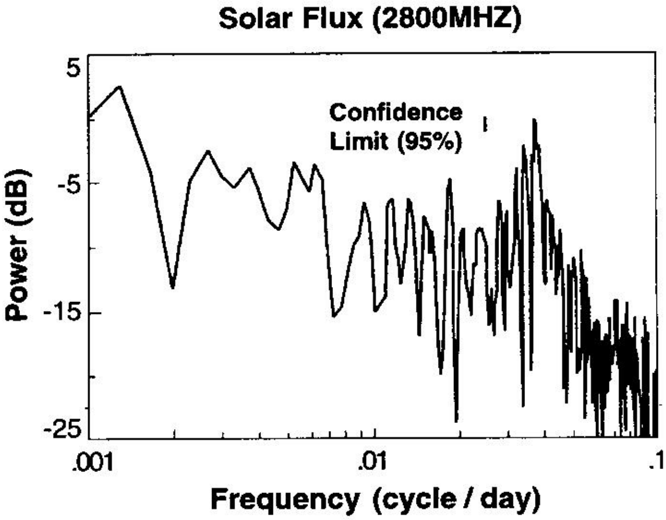


Fig. 1.5 Temporal spectrum of solar microwave flux for cycle 22

From the observations of 3C48, spatial roll off frequency was obtained. Solar wind speeds at the point of closest approach of Sun measured by IPS method are back projected to the solar corona, using 'garden hose' model. This scheme provides estimation of solar plasma acceleration and its values for the year 1987-88 are found to vary from ~ 4-23 meters/sec^2. This work is being carried out in collaboration with Dr.K.N.Iyer, Physics Department of Saurashtra University and Dr.M.Kojima of STE Lab, Nagoya University, Japan.

(Hari Om Vats, R.M.Oza, M.R.Deshpande, K.J.Shah, and Chhaya R.Shah)

Photospheric, Chromospheric and Coronal Study of the Active Region NOAA 7978 during Five Disk Passages

The evolution of the photospheric and chromospheric magnetic field along with the HeI 10830 A spectroheliograms and YOHKOH soft X-ray images of the active region NOAA 7978 during its five successive disk passages during July-October 1996 was studied. The active region had three distinct phases of evolution. During the first phase, there was intense flux emergence and its interaction with the neighbouring remnant of the active region NOAA 7958. The interaction produced a sheet of unipolar region of positive field on which a

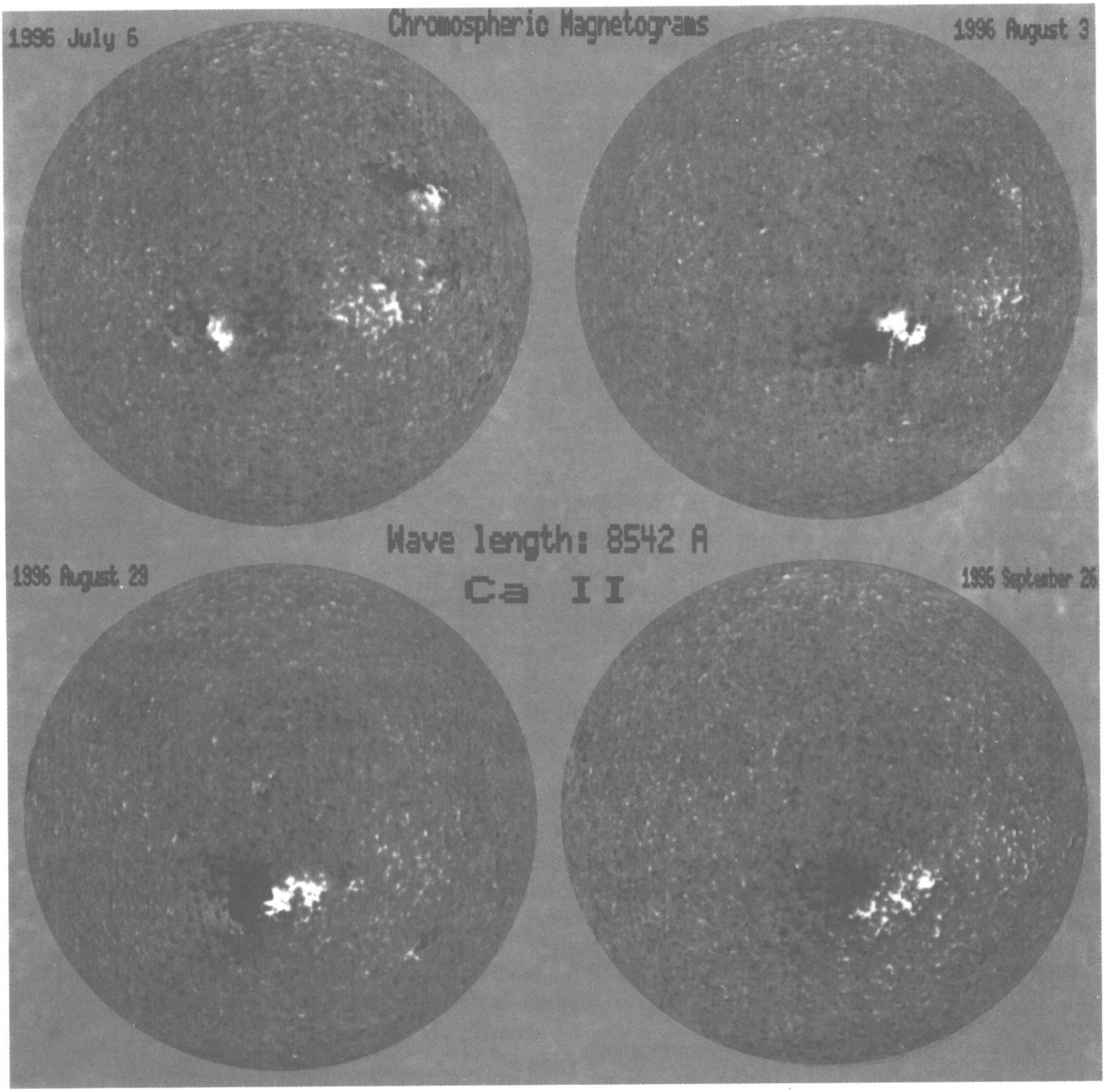


Fig.1.6 Full disk solar chromospheric magnetograms taken during four successive solar rotations showing evolution of the active region magnetic field

coronal hole was observed. During the second phase, two large soft X-ray loop systems of 6 - 8 x 10^3km height were seen, whose footpoints connected to the magnetic field features moved leading to flux rearrangements. The third phase of the active region, having a simpler field configuration, was relatively quiet. The photospheric and chromospheric magnetograms **(Fig.1.6)** showed a flux imbalance with excess positive flux during the initial phase. This work was done in collaboration with H.P.Jones of GSFC, South-West Solar Station, National Solar Observatory, Tucson and K.L.Harvey of Solar Physics Research Corporation, Tucson.

(Debi Prasad C.)

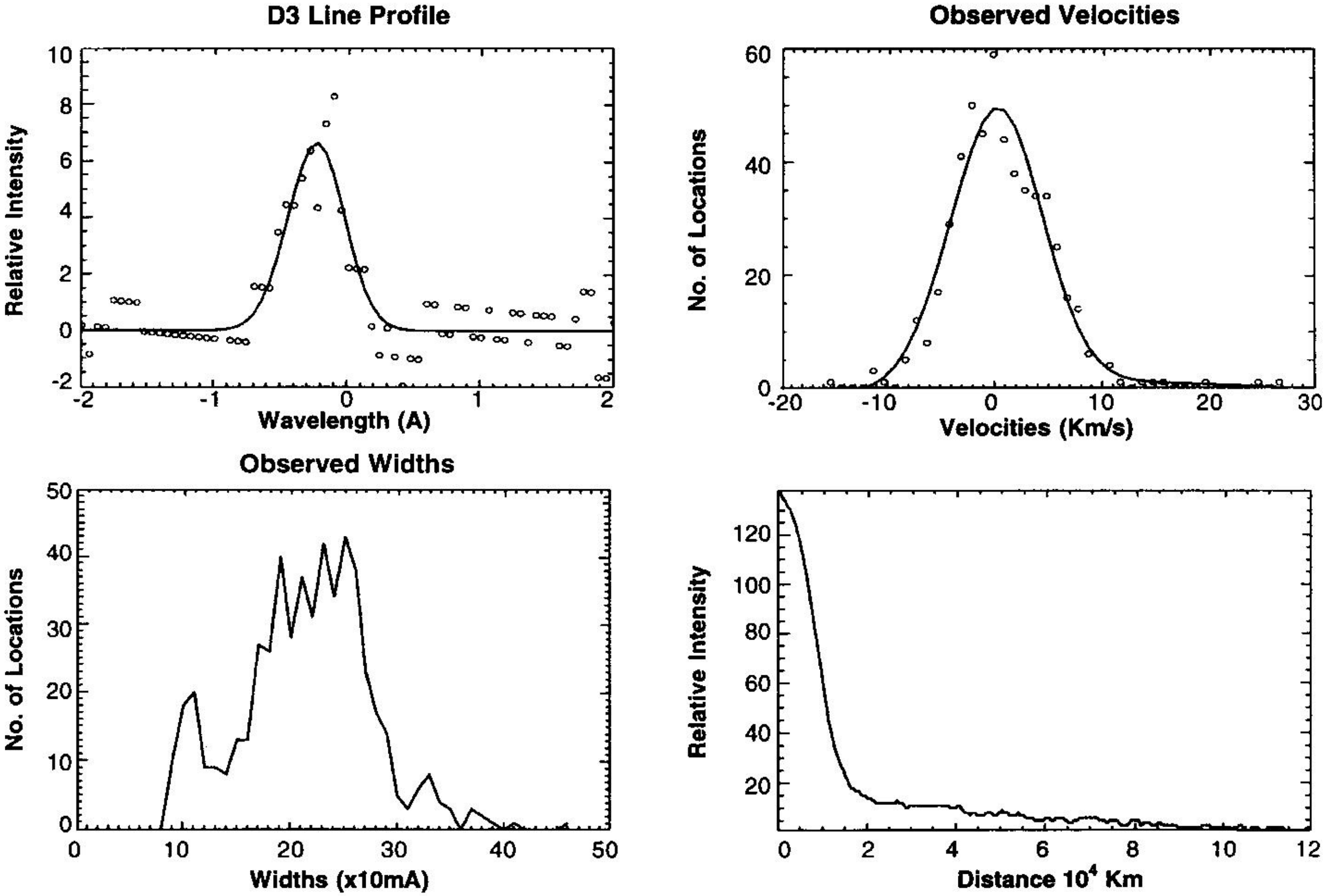


Fig. 1.7 (Top left) Example of a D3 line profile (top right). Distribution of line of sight velocities derived from about 550 spectra distributed over the prominence (bottom left). Distribution of the observed widths over the prominence (bottom right). Intensity profile of the prominence in D3 as a function of height from the solar limb.

Emerging Flux and X-class Flares in NOAA 6555

The active region NOAA 6555 had several locations of highly sheared magnetic field structure, yet, only one of them was the site for all the five X-class flares during its disk passage in March 1991. Observations of high-resolution Hα filtergrams, vector magnetograms, and Hβ Dopplergrams of the 2BX5.3 flare on 25 March 1991, show that the flaring site was characterised by a new rising "emerging flux region" (EFR) near the highly sheared magnetic field configuration. At least three of the five observed X-class showed clear signatures of pre-flare flux emergence. Hence EFRs played an important role in destabilising the observed sheared magnetic structure leading to large X-class flares. This work was carried out in collaboration with Dr.G.Ai of Beijing Astronomical Observatory, China.

(Debi Prasad C. and Ashok Ambastha)

Study of Solar Prominence in He D3 Emission

Helium D3 emission at 5876A is an important tool for studying prominences, since it probes a very narrow thermodynamic condition. Analysis of He D3 line spectroscopic data **(Fig.1.7)** for a quiescent prominence obtained by USO Coude Spectrograph showed the line-of-sight velocities in the range ± 4.2 km/s. The micro-turbulence velocities are found to peak around 4 km/s. These results are in good agreement with the previous

The main interest in the Theoretical Physics group is to understand the fundamental interactions in Nature in both macro- and micro-systems, using analytical and computational techniques. Broadly the research carried out is subdivided under headings: Atomic and Molecular Physics, Gravitation Physics, High Energy Physics, Nuclear Physics, Plasma Physics, Nonlinear Dynamics and Computational Physics.

GRAVITATION PHYSICS

Gravitational Waves

One of the basic features of studies in gravitational waves concerns their propagation which is analysed using linearised perturbations of Einstein's equations with source term providing the medium. Using a multicomponent field analysis formulation of the WKB method adopted to study the characteristics of the second order partial differential equations (a method developed in 1987) we have studied the propagation of gravitational and sound wave modes in a perfect fluid distribution. The analysis bears out the possibility of wave-medium interaction for both modes. The transport equation for the secondary amplitude of the gravitational wave mode is inhomogeneous and includes the curvature dependent terms along with matter pressure and density. Further studies in this context are pursued by setting up a proper matter model that include dissipative terms like viscosity shear and expansion. There are indications that the presence of these could already influence the transport of even the primary amplitudes, depending possibly on polarisation. This work was done in collaboration with Prof. J. Ehlers.

(A.R. Prasanna)

The spiralling compact binaries are the most promising sources of gravitational radiation in the near future for ground-based laser interferometric detectors like LIGO and VIRGO. The extraction of information carried by these waves requires theoretical templates of very high accuracy. We have recently derived a general formula accurate to 4.5PN order ($O((v/c)^9)$) for the gravitational radiation in binary systems. The formulation is valid for general orbits and for a class of coordinate gauges. The method used is a refined form of energy and angular momentum balance. A critical analysis of the features of this method has also been performed. Work on extending this method to include momentum balance is currently in progress. This will provide information on the recoil of the center of mass of the system. This work was done in collaboration with Drs. A. Gopakumar and B.R. Iyer.

(Sai Iyer)

Inertial Forces in General Relativity

Using the co-variant expressions for the inertial forces in general relativity as given by Abramowicz et al. we have defined a new concept called the 'cumulative drag index', which characterises the intrinsic rotation features of the stationary space time. The behaviour of the index at the orbit of a circularly moving particle with no centrifugal force, highlights the effect of inertial frame dragging and appears to make no distinction between blackhole and cosmological space time with rotation, for co- and counter-rotating particles. This feature seems to emphasize the so called Mach's principle with the global features of rotation influencing the local kinematics of particle motion.

(A.R. Prasanna)

Generalising the index to orbits where the centrifugal force is nonzero, we have demonstrated the possible physical significance of the index through discussions in Kerr- geometry and the Neugebauer-Meinel metric representing a self gravitating disk of dust. The behaviour of the index in both these space times is remarkably similar and it gets easier to identify the last retrograde particle orbit, which in the disk geometry gets coupled to the redshift value Z.

(A.R. Prasanna and Sai Iyer)

Centrifugal Force and Ellipticity Behaviour

Using the earlier version of the definition of inertial forces through optical reference geometry, we have studied the behaviour of centrifugal force on a fluid element and the ellipticity of the configuration for a slowly rotating fluid configuration a la Hartle-Thorne, deriving a general expression for the ellipticity, using Newtonian force balance equation in the conformally projected absolute 3-space. Whereas the centrifugal force reversal occurs at around $1.45R_S(R_S = 2GM/c^2)$ the ellipticity maximum occurs around $2.75R_S$. The results have been compared with that of Chandrasekhar and Miller, which was obtained in the full 4-dim formalism.

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

Extending the work to the case of fluid configurations with different equations of state it has been found that the location of the centrifugal maxima gets farther away from R_S as the equation of state gets softer. Whereas the ellipticity as calculated from the usual definition shows maxima, the one defined through inertial forces shows a negative behaviour indicating that the system gets prolate and not oblate. The result is similar to the one found by Pfister and Braun for a rotating shell of matter using the correct centrifugal force expression for the interior.

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

Relativistic Astrophysics

Magnetised Accretion Disk Studies

Extending the studies of magnetised fluid disk in the Newtonian formulation to general relativistic regime, we have examined two classes of magnetohydrodynamic solutions of a nonaccreting thick disk in the corotation regime of a magnetised compact object, using Schwarzschild background geometry. Unlike in the Newtonian case, here the inequalities binding the α and β parameters for having the pressure positive and the local maximum to occur at the equatorial plane, are functions of the radial Schwarzschild coordinate r. However there appears no significant change in the magnetic field topology from that in the Newtonian case. Importance of the solutions in the context of magnetised neutron star is discussed.

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

Structure of Electromagnetic Field and Charged Particle Trajectories

In view of the possible applications to the study of the magnetosphere of slowly rotating neutron star we have first obtained the structure of the electromagnetic field on the linearised Kerr metric (considering rotation parameter upto first order) and subsequently studied the charged particle trajectories therein. Depending upon the usual constants of motion and the rotation parameter, trapped, bound orbits are found to exist both for co- and counter-rotating charged particles as shown by the structure of the potential wells. Actual orbits both on and off the equatorial plane are presented, which could indeed give some idea of the shape and size of the magnetosphere.

(A.R. Prasanna and Anshu Gupta)

Continuing the above studies for the structure of the electromagnetic fields in the interior, we have studied the effects of rotation as well as of different equations of state on the magnetic field topology in the interior using the continuity of the field at the surface. Here again the geometry in the interior is taken to be as given by the Hartle-Thorne metric, which represents the fluid distribution in a slowly rotating star.

(Anshu Gupta and A.R. Prasanna)

Photon Trajectory in Curved Space Time

We have derived the wave equation obeyed by electromagnetic fields in curved space time. We find that there are Riemann and Ricci curvature coupling terms to the photon polarisation which result in a polarisation dependent deviation of the photon trajectories from null geodesics. Photons are found to have an effective mass in an external gravitational field and their velocity in an inertial frame is in general less than c. The effective photon mass in the Schwarzschild metric is $m\gamma = (2GM/r^3)^{1/2}$ and near the horizon it is larger than the Hawking temperature of the blackhole. We also show that there is no superluminal photon velocity in higher derivative gravity theories (arising from QED radiative corrections), as has been claimed in literature. We show that these erroneous claims are due to the neglect of the Riemann and Ricci coupling terms which exist in Einstein's gravity.

(S. Mohanty and A.R. Prasanna)

ATOMIC AND MOLECULAR PHYSICS

Charge Transfer in Energetic Ion-Atom Collisions

An overview of some recent developments in charge transfer in fast ion-atom collisions at nonrelativistic energies is presented. The theoretical methods are critically examined and some illustrative comparisons with experimental data are presented.

(D.P.Dewangan)

Excited-states to Excited-states Transitions of Atoms

In this ongoing project, we are working on a multiple scattering model in which the scattering wave function for the initial channel contains a product of two Coulomb wave functions. The model includes a closured second Born term fully and also contributions from both real and imaginary parts of the third and all higher-order closured Born terms. For numerical computation, the transition amplitude of the model is reduced to a three-dimensional integral expression. The integrand contains distorted Green's functions and other (branch point) singularities because of which the tranisition amplitude cannot be computed directly by applying standard quadrature formulas. Moreover, the mathematical form of the integrand depends on the orbital and magnetic angular momenta of the initial and final atomic states. We have developed new techniques for evaluating such singular integrals for ns → n's and ns → n'p transitions and have written a computer code. The computer programming is involved and tricky and its computation takes considerable amount of CPU time. We have calculated the angular correlation parameters for electron impact excitation of H(2p) which provides the most stringent test of a theoretical model. A most striking result of the study is that in contrast to existing theories, the present model, for the first time, gives an excellent agreement with the experimental R parameter for larger scattering angles at 54.4 eV.

(D.P. Dewangan)

Closured Second Born Amplitudes for Arbitrary Transitions

In the literature, the second Born amplitudes are computed by applying parametric differentiation method to the Lewis three denominator integral. This method becomes very cumbersome and even unmanageable when dealing with excited states. We have been able to devise a new technique which does not depend on the method of parametric differentiation. In this technique the second Born amplitude is reduced to a two dimension integral for arbitrary nlm → n'l'm' transitions in a form suitable for numerical computation.

(D.P. Dewangan)

HIGH ENERGY PHYSICS

Neutrino Masses and Supersymmetry

Supersymmetric standard model is known to violate lepton number due to presence of additional fields which carry lepton number. One of the consequences of this violation is generation of neutrino masses. Detailed structure of neutrino masses and mixing was worked out analytically under a specific assumption that the lepton number violation occurs only through dimensionful parameters. Restrictions on these parameters and feasibility of accounting for different neutrino anomalies in this scenario was worked out in collaboration with K.S. Babu, Institute of Advanced Studies, Princeton, USA.

(A.S. Joshipura)

Gauge Mediated SUSY Breaking

The above framework of neutrino mass generation gets severely constrained if breaking of supersymmetry occurs through gauge interaction. The minimal scenario in this context has basically one dimensionful parameter. The structure of neutrino masses and mixing was studied in theories with gauge mediated supersymmetry breaking.

(A.S. Joshipura and V. Sudhir Kumar)

Neutrino Mass and HERA Events

Lepton number violation can also arise in supersymmetric theory through dimensionless Yukawa couplings. e^+p collider at HERA seems to be hinting towards presence of lepton number violation of this type.

Compatibility of this interpretation with bounds coming from neutrino mass was analyzed in detail. It was shown that the neutrino mass constraints considerably limits the possibility of interpreting HERA data in terms of the production of squark through its lepton number violating couplings.

(A.S. Joshipura, V. Ravindran and V. Sudhir Kumar)

Production Process Dependence of Neutrino Flavour Conversion

We perform a covariant wavepacket analysis of neutrino oscillations taking into account the lifetime of the neutrino production process . We find that flavour oscillations in space are washed out when the neutrinos are produced from long lived resonances and what can be observed in appearance/disappearance experiments is a uniform conversion probability independent of distance. The effective baseline of the experiment is $c\tau$ - the lifetime of the resonance which produces the neutrinos. For this reason the LSND experiment where neutrinos are produced from muon decay has two orders of magnitude more sensititivity to neutrino mass square difference than other experiments (where the neutrinos are produced from pion or kaon decays). Using the covariant conversion probability formula we find that the region of Δm^2 and $\sin 2\theta$ which is allowed by LSND and all other experiments.

(Subhendra Mohanty)

Λ Production in Polarised $e^+ e^-$ Annihilation

The knowledge of polarised fragmentation functions of quarks and gluons into polarised Λ would be useful in testing various existing models to explain Λ production. The Q^2 evolution of the polarised fragmentation functions of quarks and gluons in Perturbative Quantum Chromodynamics has been studied using the Altarelli-Parisi evolution equations governing them. Interestingly, it is found that the first moment of polarised gluon fragmentation function is as important as that of quark and anti-quark fragmentation functions. Hence, a factorisation method has been proposed to compute the gluonic contribution to Lambda production in e^-e^+ annihilation. With appropriate operator definitions for the quark and the gluon fragmentation functions, it is found that the hard part of the factorisation formula is free of any infrared singularities confirming the factorisation to order $\alpha_s(Q^2)$. It is also found that these corrections are ultraviolet scheme dependent in the sense that the operators appearing in the factorisation formula are renormalised in minimal subtraction scheme. The status here is very similar to the gluonic contribution to various structure functions appearing in DIS. The QCD corrections to the asymmetries discussed in the paper of Burkhardt and Jaffe, which demonstrates the extraction of various fragmentation functions, have also been calculated.

(V. Ravindran)

Polarised Structure Function $g_s(x,Q^2)$

The transversly polarised structure function $g_s(x,Q^2)$ of the proton measured recently has gained lot of attention as it lacks parton model interpretation. $g_2(x,Q^2)$ is controlled by the off-shell partons and their interactions. It requires careful identification of higher twist operators. It has been found that the combination $g_1(x,Q^2)+g_2(x,Q^2)$ (usually denoted by $g_T(x,Q^2)$) is much more interesting than $g_2(x,Q^2)$ alone both from a theoretical and experimental point of view as it has simple parton model interpretation as well as factorisation property at the twist two level. Factorisation of mass singularities (soft and colinear) has been established at the level of gluonic coefficient function appearing in the factorisation formula.

(V. Ravindran)

Lepton Flavour Violation in a Model for Neutrino Masses

Models suggested for understanding the smallness of neutrino masses can have interesting phenomenological consequences which can be tested. Study was undertaken of a model for radiative neutrino masses suggested by Babu, simply modified to incorporate spontaneous lepton number violation and, consequently, a Majoron J. It was found that charged scalars at one-loop level can make significant contribution in the decay $Z \rightarrow H\gamma$ where H is a massive scalar Higgs. Consequently, it can give rise to an interesting monochromatic spectrum for the photon, accompanied by invisible Higgs decay, for a certain range of parameters. For another range of parameters, the model predicts a significant branching ratio for $Z \to JJ\gamma$, with its characteristic signal of a continuous spectrum for the photon accompanied by missing energy. This work was done in collaboration with J.W.F. Valle of University of Valencia and J.F. Romao of Inst. Superior Técnico, Lisbon.

(S.D. Rindani)

CP Violating Gauge Boson Couplings and Their Signatures

The simple idea of CP-violating forward-backward asymmetry of Z has been used to suggest a method of isolating a single CP-violating anomalous W^+W^-Z coupling (out of a total of three possible ones) in the reaction $e^+e^- \to \nu\bar{\nu}Z$. This process has the advantage over $e^+e^- \to W^+W^-$ of measuring the W^+W^-Z coupling independently of the $W^+W^-\gamma$ coupling. The prospects of observing this asymmetry and the measurement of the coupling at a future linear e^+e^- collider have been discussed. This work was done in collaboration with J.P. Singh of M.S. University of Baroda.

(S.D. Rindani)

CP Violating Dipole Couplings

Gauge models of leptoquarks with couplings only to third-generation quarks and leptons have been investigated for one-loop contributions to electric and weak dipole moments of the top quark and the tau lepton. Data on dipole moments of the tau can be used to constrain the masses and couplings of leptoquarks. These constraints can then be used to predict the range of possible top dipole moments in the model. The results are in the range of values which can be explored in future experiments which are in the planning stage.

High-energy photon-photon collisions can be achieved with the use of laser backscattering from high energy electron beams. The possibility of measuring the top dipole moments in such experiments has been explored. New CP-violating asymmetries have been suggested using circularly polarized photons and longitudinally polarized electron beams. The limits that these asymmetries can put in the case of a planned experiment have been worked out.

(P. Poulose and S.D. Rindani)

Cerenkov Radiation of Longitudinal Photons by Neutrinos

In a relativistic plasma neutrino can emit plasmons by the Cerenkov process which is kinematically allowed for a range of frequencies for which refractive index is greater than one. We have calculated the rate of energy emission by this process. We compute the energy deposited in a stalled supernova shock wave by the Cerenkov process and find that it is much smaller than the Bethe-Wilson mechanism.

(Sarira Sahu)

Axial Vector Coupling Constant in Chiral Colour Dielectric Model

The axial vector coupling constants of the ß decay processes of neutron and hyperon are calculated in SU(3) chiral colour dielectric model (CCDM). Using these axial coupling constants of neutron and hyperon, in CCDM we calculate the Ellis-Jaffe sum rules for neutron and proton. Our result is similar to the results obtained by MIT bag and Cloudy bag models.

(Sarira Sahu)

Neutrino Propagation in a Random Magnetic Field

The active-sterile neutrino conversion probability is calculated for neutrino propagating in a medium in the presence of random magnetic field fluctuations. Necessary condition for the probability to be positive definite is obtained for active-sterile electron neutrino conversion in the early universe hot plasma and in supernova and this put limit on the neutrino magnetic moment.

(Sarira Sahu)

Test of Equivalence Principle from Neutrino Experiments

At present the solar and atmospheric neutrino puzzles, and the excess ν_e events at the LSND indicate an oscillation of $\nu_e \rightarrow \nu_\mu$. Mechanisms underlying neutrino oscillation typically assume that neutrinos have nondegenerate masses. In this scenario the weak interaction eigenstates of neutrinos are distinct from their mass eigenstates, thereby permitting oscillations between the various flavours. We consider the hypothesis that all neutrino oscillation data can be explained if the gravitational couplings of (massless or degenerate mass) neutrinos are flavour non-diagonal, in violation of the equivalence principle. We analyzed the various neutrino oscillation laboratory experimental data including the recent LSND observation to constrain the relevant parameter space. We find that there is no allowed region of parameter space which can explain the existing data, implying that the LSND result cannot be explained by oscillations of degenerate-mass neutrinos due to equivalence principle violations. This work was done in collaboration with R.B. Mann of University of Waterloo, Canada.

(U. Sarkar)

Leptogenesis

One of the most important problem in particle physics and cosmology is the question of baryogenesis. The large asymmetry observed today correspond to $n_B - n_{\bar{B}} / n_B \sim 3 \times 10^{-8}$ at early times. This can be explained naturally in models where there is out-of-equilibrium baryon number violation and C and CP are also violated. Few years back it was shown that if there is enough lepton asymmetry in the universe at very early times (at a temperature $T \sim 10^7$ GeV), that can also give us baryogenesis during the electroweak phase transition (at a temperature $T \sim 10^2$ GeV). This mechanism is called leptogenesis. We have shown that in left-right symmetric models it is possible to have $SU(2)_R$ symmetry breaking through a first order phase transition, which may allow low energy leptogenesis.

(A. Ganguly, J.C. Parikh and U. Sarkar)

We have studied the question of CP violation in the generation of baryon assymetry and have shown that there can be a new type of CP violation contributing to leptogenesis. Unlike the conventional mechanism where the CP violation enters in the decay of heavy particles, in the present scenario it enters in the mass matrix. This work was done in collaboration with M. Flanz and E.A. Paschos of the University of Dortmund, Germany.

(U. Sarkar)

NUCLEAR PHYSICS

Dynamical Symmetries For Proton Rich Nuclei

Radioactive ion beam (RIB) facilities offer the opportunity of exploring new regions of nuclei far off the valley of stability. Before data on such exotic nuclei becomes available, it is clearly desirable to have model predictions for such nuclei as they may provide guidance for new experiments to come. For example the RIB facilities will allow in near future to study heavy nuclei with protons and neutrons filling the same major shells like proton rich nuclei with N ~ Z ~ 40 and lighter isotopes of Tellurium, Xenon and Barium. During 1996-97 study of dynamical symmetries of proton rich nuclei is initiated for the first time. In the last one year, it is recognized that the dynamical symmetries of an isospin (T) invariant (sd) interacting boson model with not only good T but also good s and d boson isospins (T_S, T_d) carry signatures typical of some heavy (proton rich) N ~ Z nuclei (^{64}Ge, ^{64}Zn). It is shown that with good (T_s, T_d) there are three dynamical symmetries and they are called $[U_d(5) \otimes U_{T_d}(3)] \otimes U_{T_s}(3)$, $[U_d(15) \supset O_d(15)] \otimes U_{T_s}(3)$ and $O_{sd}(18) \supset O_d(15) \otimes O_{T_s}(3)$ limits; the last two symmetry limits carry α-particle like correlations. The symmetry limits with $U_d(5)$ and $O_d(15)$ are identified by PRL scientists and the limit with $O_{sd}(18)$ was identified by scientists at Los Alamos. The low-lying phonon multiplets generated by the three symmetry limits are found to carry clear signatures of isospin in spectra; the spectra for T= 0 nuclei are quite different from the standard T= N (N is boson number) spectrum. For T= 0 nuclei, a formalism for calculating electric quadrupole transition strengths (B(E2)'s) in the three symmetry limits is developed. To this end transformation brackets between $U(N) \supset SO(N) \supset SO(N_a) \otimes SO(N_b)$ and $U(N) \supset U(N_a) \otimes U(N_b) \supset SO(N_a) \otimes SO(N_b)$ for symmetric U(N) irreducible representations are derived for any N_a, N_b by using bispherical co-ordinates in $N = N_a + N_b$ dimensions and a novel convolution identity for generalized Laguerre polynomials. In all the three symmetry limits large number of formulas for B(E2)'s are derived by PRL scientists. Future RIB experiments testing these predictions will establish the applicability of the three symmetry limits for N ~ Z proton drip line nuclei.

(V.K.B. Kota)

PLASMA PHYSICS

Langmuir Waves in a Dusty Plasma with Variable Grain Charge

Nature of longitudinal plasma oscillations in a dusty plasma in the presence of dust charge fluctuations is uncertain. There are many claims that such oscillations are unstable. However, the reason for the instability is not clear. Using the self-consistent charge dynamic equations developed by us (Bhatt and Pandey, 1994), we have shown that instability in the plasma oscillations arise due to improper treatment of the dust charge dynamics and if one considers the self-consistent charge dynamics the instability disappears.

(J.R. Bhatt)

Low Frequency Waves in Magnetized Dusty Plasmas in the Presence of Grain Charge Fluctuations

In most of the space and astrophysical plasma environments one encounters the presence of magnetized dusty plasmas. We have investigated the role of dust charge dynamics on the low frequency behaviour of the plasma. Especially we have found that Alfvén waves in such a plasma are strongly damped due to the grain charge fluctuations. This grain charging process, in certain situations, provides an efficient damping mechanism for the Alfvén waves in a dusty plasma. Such effects can have some important consequences for the interstellar clouds. We also find that due to the grain charge fluctuations, in certain situations, the plasma is having non-zero streaming, low frequency transverse waves become unstable. This work was done in collaboration with A.A. Sheikh.

(J.R. Bhatt and A.C. Das)

Linear and Nonlinear Dust-acoustic Waves in Dusty Plasmas

Using the kinetic theory, it is shown that the small, but finite, amplitude dust-acoustic waves (DAW) in a dusty plasma are governed by a kinetic Korteweg-de Vries (KDV) equation which is structurally similar to its fluid counterpart but has a more general set of coefficients for the various terms. Results show that the soliton amplitude and the width as predicted by the kinetic theory significantly differ from those of the fluid model at larger electron-to-ion temperature ratios. This part of the work was done in collaboration with S. Vidhya Lakshmi, R. Bharuthram and P.K. Shukla.

Recent experiments show that DAW exist in the very low-frequency regime of a few Hz, and hence the need to study them using the adiabatic equation of state. Our results show that while in the linear regime the usual γ-model and the full adiabatic equation of state lead to essentially the same dispersion relation, for nonlinear waves the presence of adiabatic dust particles give rise to quantitative differences. On the other hand, in inhomogeneous plasmas, the propagation characteristics of DAW is affected by the presence of the dust density inhomogeneity. In particular, the amplitudes of the linear as well as the nonlinear DAW decrease as the waves propagate into regions of higher dust density.

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

Coupled Helicons and Phonons in Dispersive Media

The nonlinear dynamics of coupled helicons and phonons in dispersive media such as plasmas is shown to be governed by a system of coupled Schrödinger-Boussinesq equations. For stationary waves, the coupled system reduces to a generic Hamiltonian of the Hénon-Heiles type which admits indefinite kinetic energy. The generic Hamiltonian is shown to be integrable for three sets of parameter regimes. It is found that the helicon-phonon system provides a physical model which is integrable for both positive and negative group dispersion of the helicons. This work was carried out in collaboration with P.K. Shukla.

(N.N. Rao)

Upper-hybrid Wave Excitation from O-mode in the Ionosphere

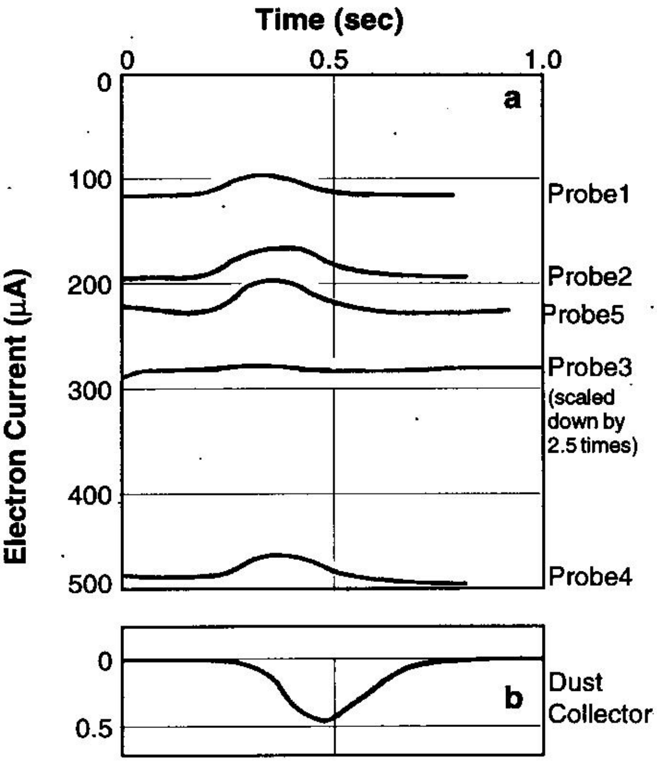
One of the important processes in the artificial modification of the ionospheric F-region plasma by means of intense radio waves is the excitation of the upper-hybrid (UH) waves by the incident O-mode electromagnetic wave. We have completed the linear analysis of this problem by showing that the "direct conversion" process could lead to strong excitation of the UH waves in the resonance region. The model used is that of a driven harmonic oscillator in which the electron drift velocity induced by the O-mode beats with the local electron density to produce a source current which drives the excited UH waves. We are now looking into the nonlinear extension of this problem. This work was carried out in collaboration with S.N. Antani.

(N.N. Rao)

Charging of Dust Grains by a Flowing Plasma

An experiment is in progress to investigate the charging of dust grains injected in the path of a magnetised flowing plasma. The plasma produced by a Penning type of source is injected into an SS chamber permeated by an axial magnetic field. The magnetic field in the system is around 60Gs., so that the electrons are magnetised whereas the ions are not. A multigrid analyser is used for obtaining energy spectrum of the plasma components and the other plasma parameters are measured with the help of Langmuir probes movable along the axis of the plasma column. The dust, a fine powder of Al_2O_3 (~0.3 µm diameter) is injected by means of a "duster" so as to fall freely from the top of the plasma column. The amount of dust injected per shot is about 1mg., which amounts to ~ $2x10^{10}$ dust grains per shot. We have also recorded Langmuir probe characteristics at five different positions along the path of free fall of dust both with and without the dust injection.

Fig. 2.1a gives simultaneously the electron probe current with time on five different probes biased to +125V, positioned near the axis at distances ranging from 10.5 to 16.5cm from the exit of the duster. These plots show a depletion in the electron current which coincides in time with the passage of the dust cloud across the plasma column. The charge acquired by the shot of dust particles is estimated by letting the charged dust particles fall on an SS plate placed right below the duster at the lower end of the plasma column. The current signal registered by this plate, kept inside a cup with an aperture of 10mm is given in **Fig. 2.1b**. Being an electron current it is negative as expected. The peak of the plate current (**Fig. 2.1b**) is delayed in time with respect to the peak of the depression in the probe current and this delay of nearly 100ms matches with the time of free fall under gravity from the position of the probe to the Dust collector, starting with zero velocity at the duster exit.



Figs. 2.1a and 2.1b The electron currents registered by the Langmuir probes and the dust collector.

The values of charge acquired per grain obtained for different plasma densities are as under

Density	Charge per grain (size 0.3µm)
$1x10^{10}$ cm^{-3}	340
$6x10^{9}$ cm^{-3}	100
$1x10^{9}$ cm^{-3}	20

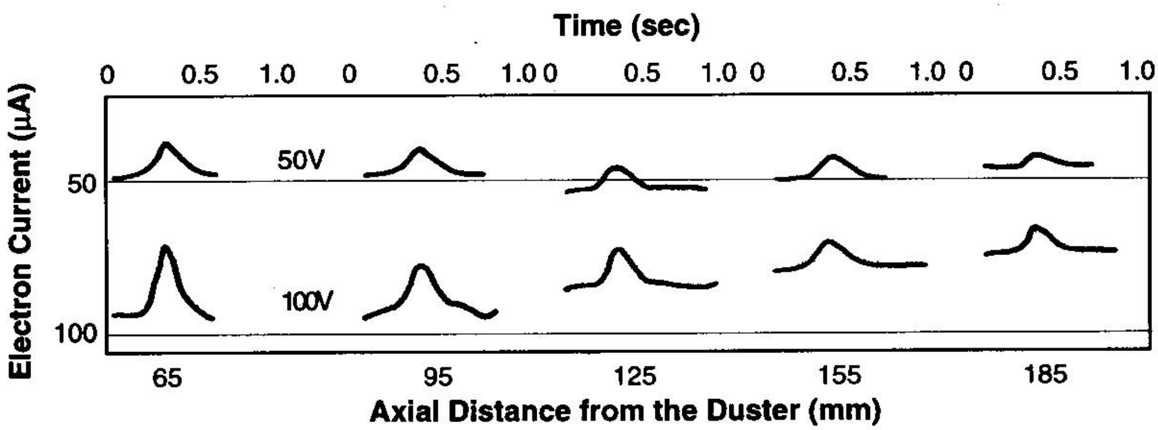


Fig. 2.2 The perturbation in the plasma at various distances from the duster due to the passage of dust

We have recorded the probe characteristics at various distances along the axis from the position where the dust is injected. A typical set of plots obtained for two different bias voltages on the probe moved to various distances from the dust injection region is shown in **Fig. 2.2.** We notice that there is an appreciable electron depletion right upto a distance of nearly 30cm away from the dust injection region. This is probably explained by the fact that, since the magnetic field restricts the motion of electrons perpendicular to it while allowing their free flow along it, the plasma electrons used up in grain charging are being drawn from other regions along the field lines.

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

NON-LINEAR DYNAMICS AND COMPUTATIONAL PHYSICS

Multidimensional Anharmonic Oscillators and Quantum Localization

Three dimensional anharmonic oscillators are being studied to explore novel higher dimensional aspects of non-linear dynamics such as Arnold diffusion. We have begun the classical and quantum studies and preliminary results confirm that, even for three dimensional systems, eigenvalue spacing distributions are the same as those for an ensemble of random matrices.

The two dimensional coupled quartic oscillator system continues to draw our attention and specifically the issue of scarring of wavefunctions. Our recent work highlights that scarring is due to adiabatically stable regions of phase space rather than due to single unstable periodic orbits. Two classes of scarred states have been singled out in the oscillators and we are studying the systematics of such states through the use of various methods including measures of localization such as information entropy and phase space representations such as the Husimi representation.

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

Relaxation Fluctuations and Quantum Chaos

Relaxation fluctuations about an equilibrium in quantum chaos have been studied. Several novel quasi-universal properties of such fluctuations have been uncovered. It has been shown that the distribution of relaxation fluctuations can distinguish whether the classical limit is chaotic or regular. Further it has been shown that if the non-linearity driving the chaos is considered as pseudo-time then the transition to chaos is quantally indicated as the relaxation of the relaxation fluctuations to a Gaussian distribution. The relevance of these results to general issues in quantum transport and an elucidation of these based on Random Matrix Theories is in progress.

(A. Lakshminarayan)

Quantum Cat Maps

Cat maps have attracted attention over the years as a model of chaos; however the quantum cat maps have several unfortunate features which make them highly non-generic for studies on quantum chaos. We have exploited a factorization of a class of toral automorphisms into three fundamental shears to provide a more canonical derivation of the quantum cat maps than the prevalent derivations (due to M. Berry and others). This allows us to exploit the freedom of the two phases defining the dual quantum torus and preliminary results indicate that these phases have dramatic quantum mechanical effects including that of pushing the cat maps into the class of generic quantized chaotic systems.

(A. Lakshimanarayan)

Asymptotic Evaluation of Gauss Sums

Gauss sums arise in several contexts, including the quantum sawtooth map, the rigid rotator, quadrapole interaction of a nucleus with an electric field, etc. We have studied the systematic asymptotic expansions of the incomplete Gauss sums as a model of the semiclassical periodic orbit sums. We have shown that the effect of classical periodic orbit bifurcations can be felt as the divergence of all the terms except the semiclassical at these points. We have derived uniform approximations that take into account these bifurcations. We have also dealt with the interesting effects of an additional phase such as might occur with the threading of the rotator with a magnetic flux line which, due to a bound state Aharonov-Bohm effect, changes the energy spectrum. This leads to dramatic consequences in the terms following the semiclassical and can have the effect of softening considerably the semiclassical effects of a bifurcation.

(A. Lakshminarayan and M.P. Mehta)

Dynamic Plus Connectionist Approach to Time Series Prediction

A hybrid approach, incorporating concepts of nonlinear dynamics in artificial neural networks (ANN), is proposed to model time series generated by complex dynamic system. We introduce well known features used in the study of dynamic systems - time delay t and embedding dimension d - for ANN modelling of time series. These features provide a theoretical basis for selecting the optimal size for the number of neurons in the input layer. The main outcome of the new approach for such problems is that to a large extent it defines the ANN architecture and leads to better predictions. We illustrate our method by considering computer generated periodic and chaotic time series. Further, computer experiments were conducted by introducing Gaussian noise of various degrees in the two time series, to simulate real world effects. We find rather surprising results that upto a limit introduction of noise leads to a smaller network with good generalizing capability.

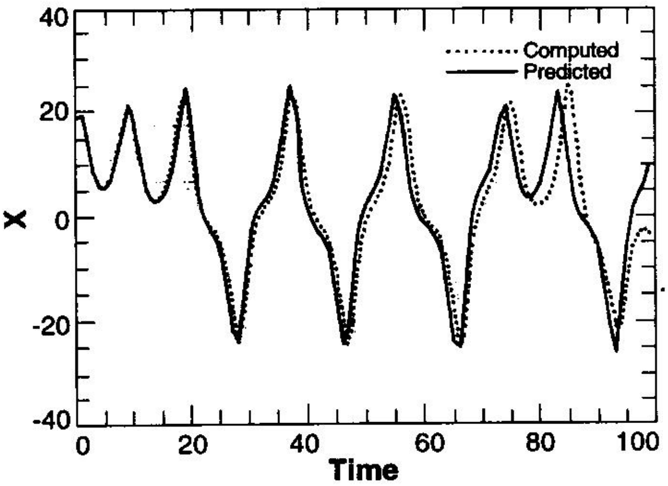


Fig. 2.3 Computed and predicted values of Lorentz's Series

Modelling Computer Generated Series

We generated 1000 points each for a regular periodic (sine) and chaotic (Lorenz's X values) time series. The first 950 points were used for modelling the series using above methodology. The ANN model developed gave excellent quality of fit for the training and test sets. The next 100 values were predicted from the model using the scheme of iterative single step predictions. The computed and corresponding predicted values of Lorenz's series are shown in **Fig. 2.3**.

(D. R. Kulkarni, A. S. Pandya and J. C. Parikh)

Modelling the Sun Spot Series

The preliminary analysis for the yearly sun spot series has been carried out. We have used 244 sun spot numbers from year 1750 to 1993. The first 226 sun spot numbers from year 1750 to 1975 have been used to model

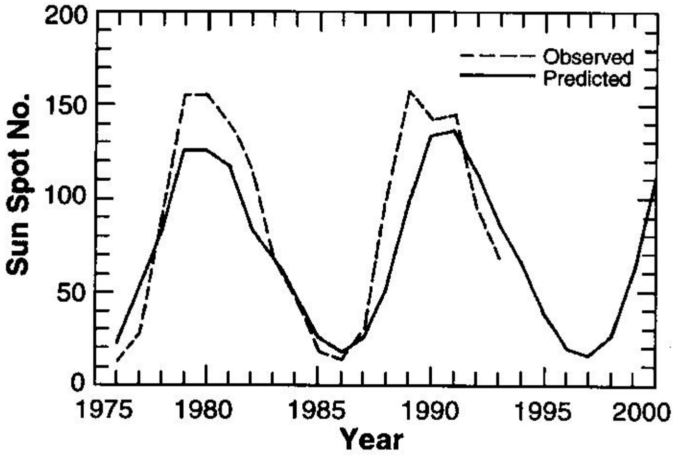


Fig. 2.4 Observed and predicted values of sun spot numbers

the series. The next 21 sunspot numbers have been predicted using the ANN model. The observed and the corresponding predicted values of sun spot numbers are shown in **Fig. 2.4**.

(D. R. Kulkarni, A.S. Pandya and J. C. Parikh)

Crime Detection System using Neural Network

Feed-back type Neural Network are being used for associative memory and recall application. A similar network (16,000 neurons and 256,000 interconnections) is developed and trained with the images of several human faces and skull. The network is then inputted with the one of the skull image. The network exhibits excellent properties of recalling the correspondence face from the several memorised faces. To confirm the above, both the sets of skulls and faces were classified using Kohanen's network in 16 different classes. In all the experiments the network confirm the true correspondence between the skull and face. The matched images were further tested using our earlier superimposition technique of marking the landmarks, matching the ratio matrix. The above technique reduced the range of search and automated the process of matching to a great extent.

(H.S. Mazumdar)

Hand Written Character Recognition

Hand written character recognition is one of the focussed area of research in the field of Artificial Intelligence. A Neural Network based algorithm is developed using Visual C++ to recognise hand written characters. The system is based on Multi Layered Feed Forward type Network with 64 binary inputs and 26 binary outputs. The software consists of different modules of page scanner, line separator, character separator, normalise, trainer and character recogniser routines.

(H.S.Mazumdar)

A Walking Robot

Multi layered neural networks are being applied in various fields of automation. One such application is developed for simulation of two legged Robot to balance and walk using Neural Network based learning technique. Human limbs are simulated and a skeleton of the human body is designed using computer graphics. A rule based Neural Network Algorithm is developed to motivate the skeleton to walk. The motivation is created using a set of rules and an error functions to achieve the set goals. Some of the goals are like- keeping the Centre of Gravity (CG) under the feet, keeping the average height of the CG constant, spending minimum energy, travelling in a given direction etc.. Using this algorithm, the seven limb joints of the skeleton are updated and the limbs are plotted iteratively to produce an animation effect of walking. The ROBOT model is only inputted with the destination coordinates, the actual movements of the limbs are generated automatically similar to human walking. The algorithm uses a technique similar to the gradient descendent method to minimise the error. Such algorithm may be applied to solve transportation problems in non-uniform space using multi legged (wheel-less) vehicles.

(H. S. Mazumdar)

METEOROLOGY AND CLIMATE STUDIES

The PRL-GCM (General Circulation Model) which was validated last year by reproducing winter and summer climates was used for sensitivity studies with natural and anthropogenic changes in the bottom boundary conditions of the atmosphere like Sea Surface Temperature (SST), surface albedo and soil moisture.

The Effects of Hydrology and Surface Albedo Changes in PRL-GCM

The Summer Monsoon is affected by surface albedo changes and soil moisture in the monsoon region. To understand the role of surface albedo changes and soil moisture, we have carried out four integrations with PRL-GCM each of 90 days, starting from 1st June and with linearly increasing surface albedo values in the Asian monsoon region with fixed values of soil moisture. It was found that as the surface albedo is increased linearly the precipitation decreases nonlinearly in the Asian monsoon region. In the other two experiments with albedo values of 0.18 and 0.24, we have decreased the soil moisture and integrated the model again. It was found that the rainfall decreased further. Thus soil moisture and surface albedo play an important role in the intensity of Asian summer monsoon. This work was done in collaboration with Dr. V. Satyan.

(S.V. Kasture and Biju Thomas)

Sensitivity of Tropical Circulation to 1987 and 1988 Sea Surface Temperature

Tropical circulation exhibited remarkable interannual variability during 1987 and 1988 associated with warm and cold phases of ENSO respectively. To model these contrasting circulation anomalies we have integrated PRL-GCM with observed monthly mean SSTs of 1987 and 1988 for eight months starting from January 1st. It was found that the summer (June-August) circulation anomalies agree reasonably well with observed circulation anomalies during 1987 and 1988. The model upper tropospheric outflow during 1988 was strong over India, Indian Ocean and western part of Australia and the inflow was strong over central and eastern Pacific ocean like observations. The upper tropospheric velocity potential minimum over western pacific shifted east by 20° during 1987 compared to its position during 1988. The model simulated Tropical Easterly Jet (TEJ) was stronger over equatorial Africa during 1988 compared to 1987. The precipitation maximum over western Pacific shifted to central and eastern Pacific during 1987 due to warm SST over central and eastern Pacific. The rainfall over southern part of India, southwest Indian Ocean and some part of Sahel was more during 1988 compared to 1987. But contrary to the observations, the rainfall was less in the northwest India during 1988 compared to 1987. This work was done in collaboration with Dr. V. Satyan.

(Biju Thomas and S.V. Kasture)

Interannual Variability of Asian Summer Monsoon

Previous observational studies have shown the existence of upper tropospheric circulation anomalies over south Asia during the winter-spring time before the strong and weak monsoons. During the winter and spring prior to a strong(weak) summer monsoon, the upper-tropospheric westerlies over subtropical Asian monsoon, are weaker(stronger) than normal. These precursory signals of monsoon are covering the subtropical Asian region for at least two seasons before summer monsoon. Some of the atmospheric general circulation models participating in the Atmospheric Model Intercomparison Project(AMIP) simulate this circulation anomalies reasonably well. But the cause and physical mechanisms responsible for these anomalies are not very clear. It is hypothesized that the circulation anomalies are linked with tropical SST anomalies or surface hydrology over Asia or it is the result of the complex interaction between these two.

We have integrated PRL-GCM for 10 years with observed SSTs from 1979-1988. The composites of upper and lower tropospheric wind anomalies are calculated for winter and spring time before strong (1984,1985,1986 and 1988) and weak (1982,1983 and 1987) monsoon years. The composite circulation anomalies simulated by GCM has good resemblance with observed circulation anomalies. This GCM does not have an interactive hydrology and among the bottom boundary conditions only SST is varying interannually. This strongly suggests that the winter-spring time circulation anomalies associated with interannual variability of Asian summer monsoon has a root cause in the variability of SST. It is possible that the changes in the heating over central and eastern Pacific remotely influence the subtropical upper tropospheric flow during winter-spring time. This work was done in collaboration with Dr. V. Satyan.

(Biju Thomas and S. V. Kasture)

Laser Physics and Quantum Optics

The research interest of the Division cover a wide range of topics, such as, optical manipulation of atoms, quantum optics of nonlinear systems, generation of giant nonlinearities, control of spontaneous emission, cavity quantum electrodynamics, generation of nonclassical light, study of new types of waveguide laser resonators and physics and technology of semiconductor lasers. The activities of this division so far have been mainly theoretical. Setting up of a laboratory to study the control of linear and nonlinear optical properties of atoms using radiation fields has been started. Some equipments have been procured and testing and installation is going on. Meanwhile collaborative experimental projects have been taken up with some groups in India and abroad. Some of the research activities are as follows:

Sub-natural Line Width Spectroscopy and Quenching of Spontaneous Emission

We show how control lasers lead to subnatural linewidths in spontaneous emission as well as to the quenching of the quantum noise. We trace this quenching to the dispersive contributions to the line shape. We obtain analytical expressions for linewidths that for Λ systems are half the natural linewidths with the possibility of much more reduction for detuned control laser. We further present a simple physical analysis in terms of a two-photon Fermi golden rule to understand cancellation of spontaneous emission. Finally, we relate our result to recent experiments.

(G. S. Agarwal)

Inhibition and Enhancement of Two Photon Absorption

It is well known from second order perturbation theory that the two photon absorption can exhibit interference minimum depending on the location of the intermediate states. The occurrence of such interferences depends on the existence of at least two intermediate states and on a special relationship between the dipole matrix elements and detunings. Thus the interference minimum in two photon absorption is determined by the intrinsic properties of the medium. We proposed a method whereby this interference minimum can be *induced as well as controlled* by changing intensity and frequency of the electromagnetic field especially applied to achieve such an objective. One thus has the possibility of making the medium transparent against two photon absorption. Clearly this control of two photon absorption should be of importance in the context of related issues like two photon lasing and pulse propagation. Further, one has the possibility of *enhancing* $\chi^{(2)}$ of media possessing small permanent dipole moment or media with strong magnetic dipole transitions. Here $\chi^{(2)}$ would essentially be proportional to two photon coherence. Studies in the reverse process, namely the two photon emission, has been initiated.

(G. S. Agarwal and W. Harshawardhan)

Sub-Doppler Light Amplification

Recently, Zhu and Lin [Phy. Rev. A 53, 1767 (1996)] reported the result of an experiment in a three-level Λ system, in which they observed amplification of a weak probe in the absence of population inversion in the bare states of the atom. They found that the linewidth associated with the gain was much less than the Doppler width, even though the experiment was in a Doppler broadened vapor of atomic rubidium. In fact, these authors found that the measured linewidth was nearly equal to the natural linewidths of the stationary atom. We show that this observation is easily explained in terms of our work [Phys. Rev. A 53, 2842 (1996)], which is generalized to correspond to the experimental situation by inclusion of incoherent pumping, and pump and probe laser linewidths. Analytical results for the linewidths were obtained. This work has been done in collaboration with G. Vemuri and B.D.N. Rao of Purdue University of Indianapolis.

(G.S. Agarwal)

Enhancement of Photon Number Squeezing

We demonstrate quenching of pump noise by two-photon resonant absorption in the cavity under competition with the one-photon process. This quenching converts largely super-Poissonian field into a sub-Poissonian one. A strong candidate for appropriate medium is Anthracene-PMDA or CuCl in a microcavity. These crystals exhibit giant two-photon absorption due to the formation of excitonic 2-string or biexcitons. We also present result for the spectral content of the cavity field which confirm the complementary nature of the amplitude and phase fluctuations. This work was done in collaboration with H. Ezaki and E. Hanamura, Tokyo University.

(G.S. Agarwal)

Realisation of Parametric Interactions in Ion Traps

We have been studying quantum dynamics of systems described by a Hamiltonian involving three wave interaction. The quantum effects are most significant if the number of photons is low. It is therefore of considerable interest to find ways in which parametric interactions can be realised. The most conventional way consists of using a non-linear crystal. We have discovered a totally new source of parametric interactions which will be especially suited for studying quantum dynamics. We show that the Raman transitions among the vibrational degrees of freedom of an ion in trap can lead to parametric Hamiltonian.

(G.S. Agarwal and J. Banerji)

Vacuum Induced Filamentation in Laser Beam Propagation

According to traditional theories, the filamentation of a laser beam as it passes through a non-linear material is a consequence of the spatial growth of weak wavefront perturbations initially present on the beam. To a certain extent these perturbations can be removed by passing a beam through a spatial filter before it enters the medium. However, quantum fluctuations in the field amplitudes of the transverse side modes impose perturbations that can not be removed by spatial filtering. These quantum fluctuations can lead to the filamentation of a beam with an otherwise perfect wavefront. We study the growth of these fluctuations and predict the non-linear phase shift at which this process will become significant. We find that quantum-initiated filamentation imposes a fundamental limit to the intensities that can be propagated through a non-linear material without beam break-up.This work was done in collaboration with E.M. Nagasako and R.W. Boyd of the University of Rochester.

(G.S. Agarwal)

Possibility of Studying Incoherent Emission Using Homodyned Spectrum

It is well known that the spectrum of resonance fluorescence from a two level system driven by a coherent field consists of a coherent component in addition to a number of incoherent components. A direct measurement of the coherent component is difficult though excellent experimental results have been obtained by homodyning. We show the possibility of using optical homodyning technique to study the *incoherent components* of Mollow spectrum as well, if monochromatic pump is substituted by a pump with finite band width. The homodyned spectrum that we use is *linear* in the scattered field and is *distinct* from the standard homodyned spectrum which involves *two orders of the scattered field.* We thus demonstrate that the finite bandwidth of the pump provides a new method of spectroscopy for studying spectral redistribution of radiation. This work was done in collaboration with T.W. Mossberg of the University of Oregon.

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

Possibility of Modifications of Quantum Jumps

Since the possibility of trapping single ions for long observation times and cooling them to states almost free of motion, single particle systems have been the object of extensive studies of fundamental light-matter-interactions. Thus, as an inherently one particle effect, quantum jumps and photon antibunching have been theoretically discussed and experimentally observed. The characteristics of quantum jumps depend critically on the different spontaneous emission rates of the system. By placing the atoms within the mirrors of an external cavity, tuned close to the transition frequency of the two upper levels, modifications in the quantum jump behaviour of the atom are shown due to a modified spontaneous decay rate between the two states. In particular, it is demonstrated that the effect of the cavity is to modify the repetition rate of quantum jumps into the metastable dark state and the average duration of bright periods of fluorescence whereas the average duration of dark periods is not changed in first order of the spontaneous decay rates involved. This work was done in collaboration with J. von Zantheir and H.

Walther, Max-Planck Institut für Quantum Optik.

(G.S. Agarwal)

Phase Conjugation Signals at Femtowatt Level

Elementary quantum mechanical analysis shows that any optical amplifier is required to add a minimum amount of noise to the input field during the amplification process. The total added noise imposes a fundamental limit on the level of the minimum signal that can be amplified for a specified value of the signal-to-noise ratio (SNR) of the output field. In a collaborative effort (with the Group at Cornell led by Prof. A.L. Gaeta and his students M.Y. Lanzerotti , R.W. Schirmer), we have studied the phase conjugate amplifiers.

We report that a phase-conjugate mirror that operates via nearly degenerate four-wave mixing (FWM) in an atomic vapor with continuous-wave fields can conjugate weak signals with power levels as small as several femtowatts with near-unity reflectivity. These power levels are the lowest that have been achieved for any PCM and demonstrate that PCMs based on resonant nonlinearities are attractive candidates for use in optical signal processing of weak signals. We find that the conditions under which the PCM operates nearest its quantum-noise limit (QNL) are similar to the conditions that permit phase conjugation of signals having the lowest power levels. We also develop a theoretical model to explain observations.

(G. S. Agarwal)

Noise Induced in Probe Radiation on Propagation through Rubidium Vapour

Introduction of noise is inherent in any amplification process. The aim of any gain mechanism is to obtain maximum gain with minimum introduction of noise by the gain process. We have studied the propagation of a weak probe beam near the $^5S_{1/2}$ - $^5P_{1/2}$ transition of rubidium vapour in the presence of a strong pump field applied between the $^5P_{1/2}$ - $^5D_{3/2}$ transition and an incoherent pump between the $^5S_{1/2}$ and $^5P_{1/2}$ levels. We have also studied a different situation to correspond to the experiments done by A. Gaeta et al of Cornell University with no incoherent pumping, but a stronger probe field applied between the $^5S_{1/2}$ and $^5P_{1/2}$ levels. We are interested in the noise that is produced in the probe beam, in the limit in which the probe beam is sufficiently strong to populate the intermediate state. We have shown that the noise in the probe frequency reduces as the resonant drive field strength is increased.

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

Generic Nonlinearities and Cat-like States

We show that the formation of Schrödinger Cat-like states under the action of various nonlinear Hamiltonians is due to the periodicity properties of the time evolution operator. Explicit analytic results for one and two-mode cases are presented **(Fig.3.1)**. Similarities with the phenomena of beam splitting inside a multimode rectangular

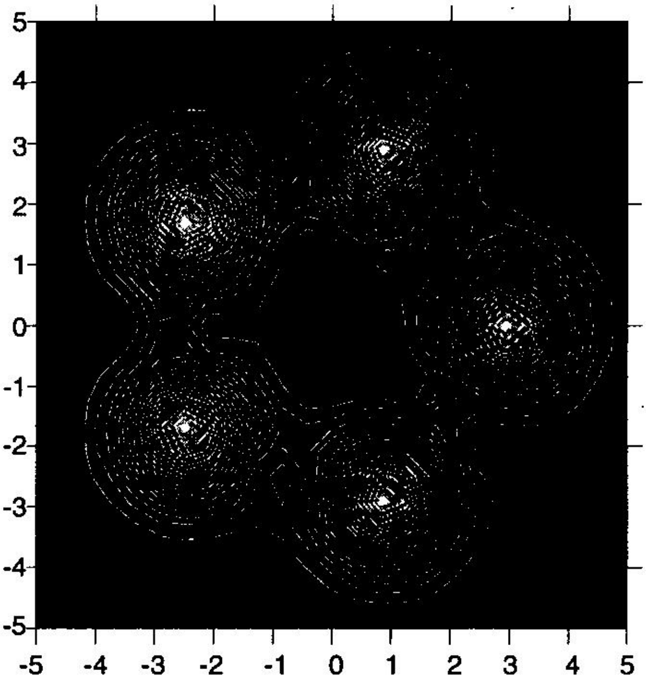


Fig. 3.1 Consider a single mode initially coherent field $|\alpha\rangle$ propagating through a Kerr medium which has a third-order nonlinear susceptibility denoted by χ . At time $t = (m/n)\pi/\chi$, (m and n co-prime), the field breaks up into a Schrödinger cat-like superposition of n equally spaced coherent states in phase space, as shown by the contour plot of the quasi-probability for $|\alpha|^2 = 9$, $n = 5$ and $m = 2$.

waveguide and revivals in Rydberg/Stark wave packets are drawn.

(G. S. Agarwal and J. Banerji)

Laser Resonators with Self-Imaging Waveguides

There are three recognised low-loss configurations for laser resonators. We have proposed a fourth one by exploiting the self-imaging properties of multi-mode waveguides. The resonator consists of a waveguide of square cross section $2a \times 2a$ and of length $2a^2/\lambda$, closed at one end by a plane mirror and bounded at the other end, by a curved mirror at a distance $a^2/(2\lambda)$ from the guide exit. The curved mirror is phase matched to an effective TEM_{00} beam of waist $\omega = 0.6\,a$ at the guide exit. For this design, a symmetric field remains unaffected by guided propagation and is efficiently coupled back to the guide by the phase matched mirror, while an anti-symmetric field suffers a two-way split at the edges of the guide exit ensuring high aperture loss on re-entry. Thus the resonator operates on the symmetric mode and filters out the unwanted anti-symmetric mode. Consequently, the resonator has a very low round-trip loss. Moreover, it is predicted to produce TEM_{00}-like output with excellent mode discrimination even though the curved mirror is placed much nearer to the guide exit (making the resonator more compact) than is conventional for achieving these results. Finally, the design parameters -guide length, guide to curved mirror distance and the mirror curvature - are functions of a and λ only. Since a and λ are arbitrary, a whole class of waveguide laser resonators can be fabricated. This work was done in collaboration with A. R. Davies , Royal Holloway and R. M. Jenkins, DRA, UK.

(J. Banerji)

Enhancement of Gain in Diode Lasers using Optical Injection

Injection locking in semiconductor lasers is a promising method to synchronise one or more than one free running lasers to a master laser. It can be used to ensure single mode operation, to reduce the spectral width, to generate optical frequency and phase modulation and to amplify the optical FM signal. Also it can be exploited to study the static and dynamic properties of the lasers. We have demonstrated experimentally that it is possible to enhance the laser gain and hence reduce the threshold by injecting a weak optical signal with appropriate frequency. The study provides a tool to monitor the spontaneous emission into the laser mode and interplay between the charge carrier generation and recombination as both of them depend on the frequency, phase and intensity of the injected signal and the operating point of the laser. Our results verify the theoretical predictions. This work was carried out in collaboration with S. Sivaprakasam of University of Hyderabad.

(Ranjit Singh)

Planetary Atmospheres and Aeronomy

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:

MIDDLE ATMOSPHERE

Subsidence of Air in the Tropical Stratosphere

Measurements of the vertical distributions of methane and other trace gases on March 27, 1987, April 9, 1990 and April 16, 1994 show disturbances around 25 km in the profiles of 1987 and 1990 as compared to the profiles of 1994. Computed model profiles of these gases using 2D model of the Max Planck Institute for Chemistry, Mainz, Germany for these three periods also confirm that the measured profiles on April 16, 1994 appear to be normal. A comparison of the estimated 'age' of the air from the measured SF_6 profiles from the 1994 samples with that obtained by German group (MPAE, Lindau), **(Fig. 4.1)** from the samples collected on March 27, 1987 show higher age of the air around 25 km than that on April 16, 1994 indicating that the air has come from higher altitudes in a quasi-vertical plane. This evidence is also supported by correlations of CH_4 with other gases measured simultaneously on both the flight dates.

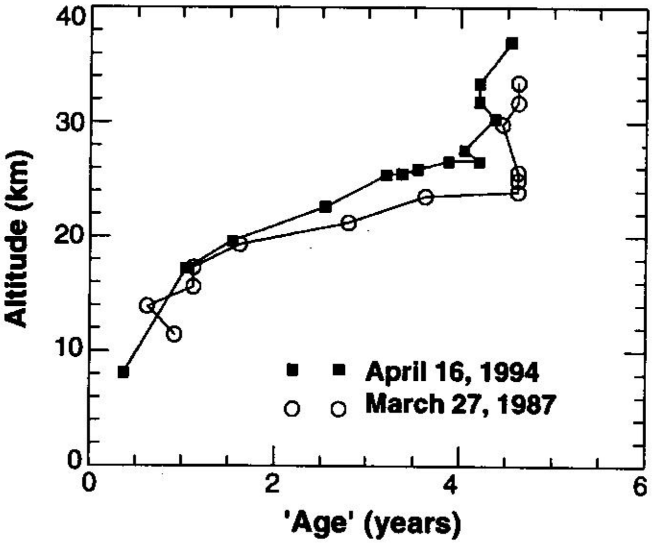


Fig. 4.1 Estimated 'age' from the profiles of SF_6 measured from the samples collected from Hyderabad on March 27, 1987 and April 16, 1994. The 'age' profile for the 1987 flight is taken from Harish et al., (1996).

(Prabir K. Patra and Shyam Lal)

Intrusion of Polluted Air in the Indian Ocean Region

Surface measurements of ozone, carbon monoxide and methane were made during a ship cruise in the Indian Ocean from January 5 to February 3, 1996. A systematic decrease in the concentrations of O_3 and CO has been observed from the coastal region to the open ocean. Ozone concentrations decreased from about 60 ppbv near the coast to as low as 7 ppbv near the equator in the open ocean. This is also supported by similar decrease in the concentrations of aerosols of sizes less than 0.5 µm. A sharp increase in the concentrations of O_3, CO and aerosols was observed around 5° N in the open ocean. The trajectory analyses show that this polluted air has come from the South Asian sub-continent. Diurnal variation in ozone in the open ocean is also observed which is similar to that observed at a free tropospheric site like Mt. Abu.

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

Annual Budget of N_2O Emission from the Arabian Sea

Extensive measurements of N_2O have been made during inter-monsoon, north-east monsoon and south-west monsoons in the Arabian Sea. Low N_2O supersaturations in the surface waters are observed during inter-monsoon compared to those during north-east and south-west monsoon. Spatial distributions of supersaturations manifest the effects of larger mixing during winter cooling and wind driven upwelling during south-west monsoon period off the Indian west coast. A net positive flux is observable during all the seasons, with no discernible differences from the open ocean to coastal regions. The average ocean-to-atmosphere fluxes of N_2O are estimated, using wind speed dependent gas transfer velocities, to be of the order of 0.26, 0.003 and 0.51 pg $cm^{-2} s^{-1}$ during north-east monsoon, inter-monsoon and south-west monsoon, respectively. A conservative estimate of N_2O emission is found to be 0.56-0.76 TgN_2O

per year from the Arabian Sea which constitute 20-27% of the global oceanic source.

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

Radiative Forcing of Aerosols over the Arabian Sea and the Indian Ocean

Accurate measurements of aerosol properties and their temporal and spatial variations are necessary to make quantitative estimate of their role in altering the Earth's energy budget and climate. A closure experiment, involving simultaneous measurements of aerosol properties and surface reaching solar radiation intensities, has been done successfully for the first time over the Arabian Sea and the tropical Indian Ocean on board ORV Sagar Kanya, during January-February 1996. A strong latitude gradient is seen both in the columnar aerosol optical depth and the mass concentration with values decreasing from the coast to the open ocean region. The sub micron size particle concentration show an order of magnitude increase near the coast compared to interior ocean region consistent with the increased aerosol optical depth obtained at lower wavelengths. The radiative forcing obtained for the direct visible (< 780 nm) solar flux show that the flux decreases by about 42 W/m^2 with every 0.1 increase in aerosol optical depth while the scattered sky radiation is found to increase with the aerosol optical depth. The coastal aerosols are more absorbing than that found over the open ocean. The coastal aerosols are composed of a variety of organic, sulfate, carbonaceous and mineral particles whereas the particles found over the open ocean region is mainly sea salt particles and sulfate particles produced in situ from sulfur bearing gases mainly of land origin. The magnitude of the gradient in aerosol mass, optical depth and radiative forcing indicates the importance of the contribution of this region to the net global radiation budget. This work is a part of the joint international research project called INDOEX (Indian Ocean Experiment) between PRL and the Center for Clouds, Chemistry and Climate, Scripps Institute of Oceanography, University of California, San Diego.

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

The MOS Data Validation Experiments over the Arabian Sea

The Modular Optoelectronic Scanner (MOS) a satellite payload developed by Germany and presently in operation on board the Indian Remote Sensing satellite IRS-P3 is a multi-spectral imaging spectrometer for remote sensing the earth's environment with special emphasis on ocean applications and aerosols. PRL is one of the active members in making necessary sea truth experiments to validate the satellite data. A total of three ship cruises have been made so far over the Arabian Sea and aerosol columnar optical depths, mass concentration, size distribution and surface reaching solar flux were measured coinciding with the satellite over head pass. The sea truth data were used to compute the back scattered sky radiation intensities at different spectral bands and compared with the satellite data. **Figure 4.2** shows the comparison between the computed radiance values for the the MOS-B channels using the aerosol size distribution measured by a Quartz Crystal Microbalance (QCM) aerosol impactor and the satellite measured radiance at the top of the atmosphere. It is also shown that radiance values obtained from the actually measured

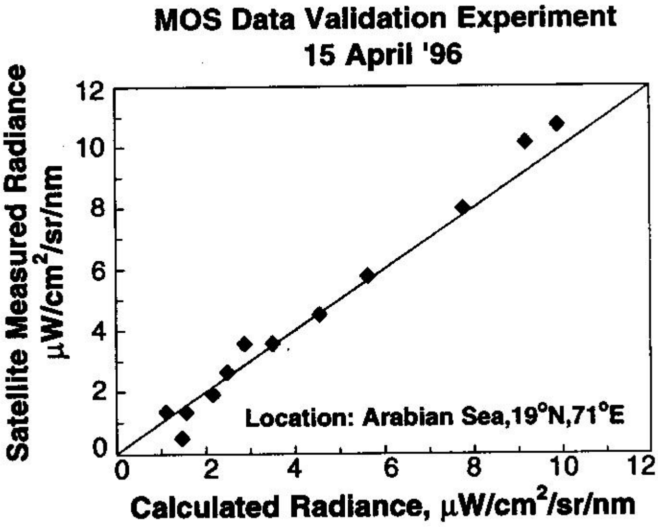


Fig. 4.2 The MOS-B measured back scattered solar radiation at the top of the atmosphere is compared with the calculated values using the aerosol size distribution measured over the Arabian Sea during a satellite overpass. Individual data points in the figure correspond to the 12 spectral channels of MOS-B from 403 nm to 1010 nm.

aerosol size distribution compare better with the satellite measured values than that computed from models. This is because, the aerosols found over the Arabian Sea is a unique combination of mineral dust particles from the surrounding arid and semi-arid regions as well as the sulfate and carbonaceous particles of anthropogenic origin apart from the commonly found sea salt particles over any ocean surface. This work is a part of the ISRO's Geosphere Biosphere Programme and done in collaboration with scientists from the Meteorology and Oceanography Group of the Space Applications Centre, Ahmedabad.

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

Atmospheric Electric Field and Seismic Activity

Vertical electric field which is an outcome of Global Electric Circuit is considered to be due to the worldwide lightning activity. On the other hand conductivity, the other important parameter in this region of atmosphere is mainly due to the ionisation by cosmic rays and is known to increase with altitude. Conductivity and electric fields have been measured over Hyderabad using balloon-borne probes. The measurements revealed, as expected by the existing models, that the conductivity is larger by a factor of two as compared to mid latitudes, while the electric fields on the other hand are larger by a factor of four, while the models predict it to be only by factor of two. This unique result suggested that there should be additional source of electric fields present, which are not accounted for by the models. In recent years, it had been reported in the literature that seismic activity could be one of the possible sources of vertical electric fields and this could even by used as a precursor to earthquakes in the larger sense. Because of its global impact, the measured differences in the vertical electric field is suggested to have its origin on phenomena like the seismic activity in the nearby region.

(S. P. Gupta)

On Significant Quantities of Free Electrons in the Upper Stratosphere over Antarctica

In the middle atmosphere below about 60 km, number of free electrons is insignificant compared to those of positive and negative ions. However, the results of a partial reflection experiment at Scott Base, Antarctica by von Biel (1995) show, very often, the presence of a layer of electron number density about 1000 cm^{-3} around 45 km. von Biel proposes that a reasonable increase in q_{cr} the electron ion production rate due to cosmic rays, can explain this feature. We have used a chemical scheme in which both positive and negative ions have been considered to explain this feature. We show that an increase of q_{cr} alone cannot explain this feature. A simultaneous increase of detachment rate of electrons from negative ions is necessary. Such an increase in detachment rate could be possible through an increase of O_3 or O or O_2 ($^1\Delta g$) densities.

(D.K. Chakrabarty)

Long Term Trend of Total Ozone over Ahmedabad

Total ozone is being measured over Ahmedabad for the past 45 years by Dobson Spectrophotometer. An examination of these ozone data from October 1951 to December 1996 have been made to make an assessment of the long term trend of ozone in this region **(Fig. 4.3)**. We do not find any decreasing trend of total ozone over Ahmedabad. This feature is attributable to different

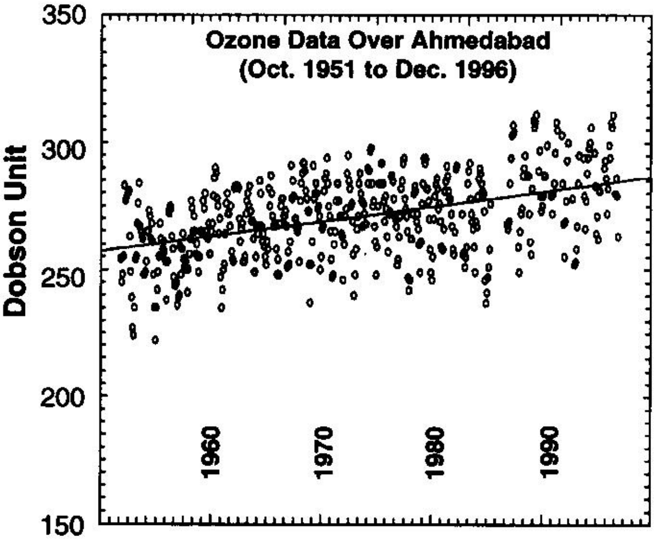


Fig. 4.3 Plot of monthly averaged values of total ozone column over Ahmedabad from October 1951 to December 1996.

type of Hadley Cell circulation over India due to the location of the Himalayas.

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

UPPER ATMOSPHERE

Parameterization of the D_{st} Index into the MSIS-Atmospheric Model

The Mass Spectrometer and Incoherent scatter (MSIS) atmospheric model is the most comprehensive and widely used model. Though the representation of the mid and high latitudes (by this model) are reasonably good, the equatorial and low latitude representation is far from satisfactory. Taking the cue from the case studies during geomagnetic storms, a detailed correlative study was performed between the D_{st} variations and the variabilities in the measured temperatures **(Fig. 4.4)**. A systematic behaviour in the time delay with season has been established along with the rate of change of D_{st} and the unexplained deviations in the temperature. The data base used for the above study is from the groundbased spectroscopic measurements and also from the DE-2 satellite. Thus by appropriately parameterizing the D_{st} into the model, almost all the variabilities have successfully been reproduced both during high and low solar epochs.

(Tarunkumar Pant and R. Sridharan)

Thermospheric Contribution to $O^1$557.7 nm Dayglow Emission

The O^1S 557.7 nm oxygen green line emission is one of the prominent emissions both during day and nighttimes. The nighttime emission has been identified to originate around 100 km as a consequence of three body reactions involving atomic oxygen and the thermospheric contribution has been estimated to be < 20%. During sunlit conditions, the whole scenario changes. By carrying out continuous measurements of dayglow emission (Na) 589.6 nm, (O^1S) 557.7 nm and (O^1D) 630.0 nm, it had been demonstrated that on most of the occasions, the thermospheric contribution reaches as high as 70% of the total intensity. This has far reaching consequences when the variations in the emission intensities are taken to represent the dynamical processes in the emitting region. These unique ground based results have been shown to corroborate well with the UARS satellite results.

(Alok Tauri, D. Chakrabarti, Tarunkumar Pant, D. Pallam Raju, N.K. Modi, R. Narayanan and R. Sridharan).

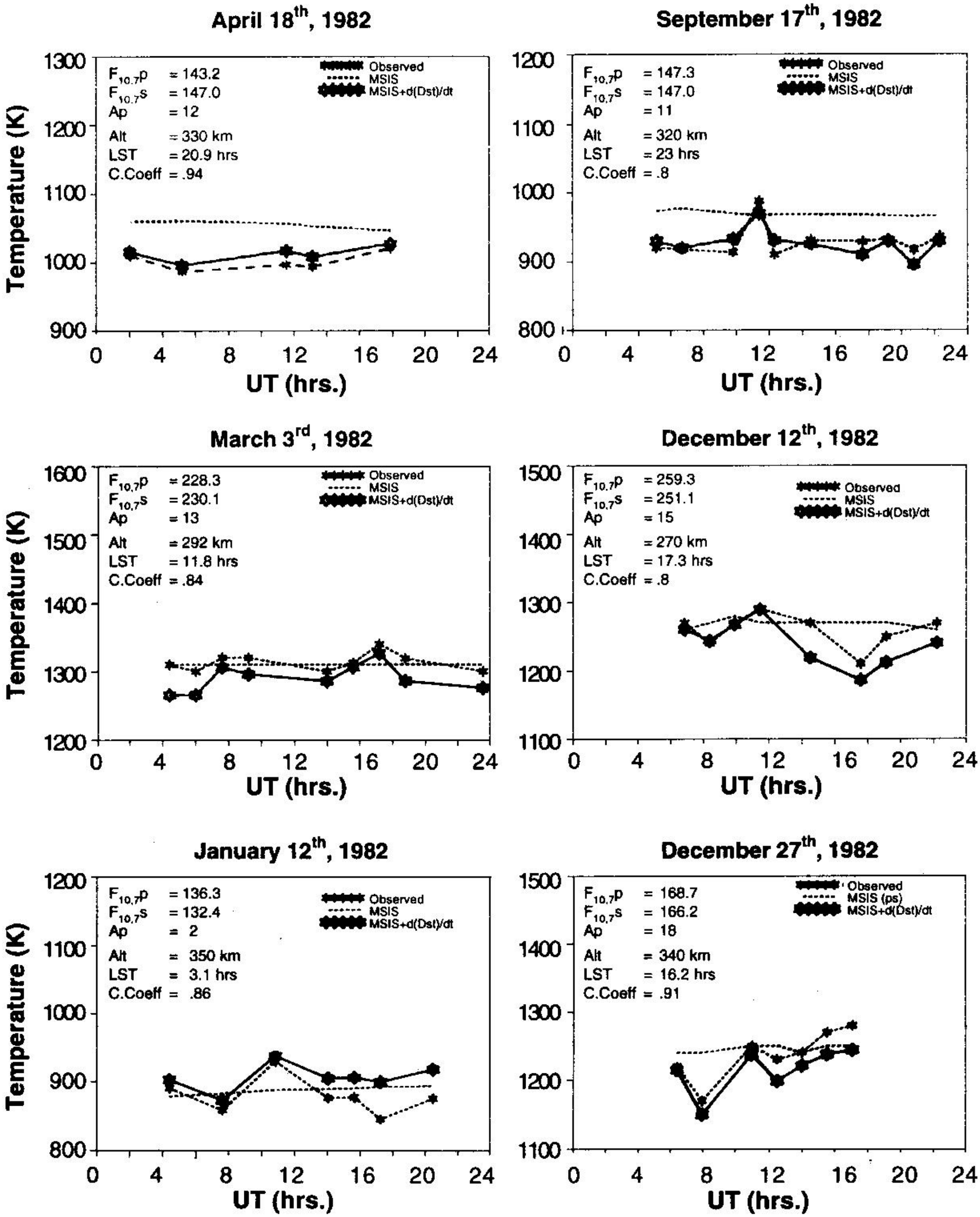
First Results on the Rotational Temperatures Estimated from the Hydroxyl Emissions during Daytime

The hydroxyl radicals in the mesopause region continuously release their excess energy in the form of Meinel bands. These emissions during daytime conditions have been used to infer the mesopause temperature, which is one of the most difficult parameters to be measured. The relative intensity of OH (8,3) band emission lines, 731.6 nm and 740.2 nm have been continuously measured using the unique multiwavelength daytime photometer, from Tirunelveli. The temperatures varied from ~ 150K to 220K during 0700hrs to 0900hrs IST revealing systematic wavy structures with periods around 1.5h. The above measurements, the first of their kind, were carried out in coordination with the UARS (Upper Atmospheric Research Satellite) measurements overhead for comparison and intercalibration.

(Alok Tauri, D. Pallam Raju, Tarunkumar Pant, D. Chakrabarti, R. Narayanan, N. K. Modi and R. Sridharan).

Local Time Variation of Equatorial Temperature and Wind Anomaly (ETWA)

The Wind and Temperature Spectrometer (WATS) data from the DE-2 satellite had been made use of in delineating the local time variability of the newly discovered phenomenon of Equatorial and Temperature and Wind Anomaly (ETWA). The ETWA is characterized by a zonal wind distribution revealing a maximum at the dip equator and two minima located around the crests of the equatorial ionization anomaly, while the temperature revealed a complementary behaviour. The most significant result being the maximum in the zonal wind occurs always over the dip equator and not over the geographic equator irrespective of direction. The zonal winds attain maximum acceleration at ~ 1700 - 1800 LST and maxi-



April 18th, 1982

September 17th, 1982

March 3rd, 1982

December 12th, 1982

January 12th, 1982

December 27th, 1982

Fig. 4.4 An example depicting the deviation of the MSIS-90 model from the DE-2 satellite measurements and the agreement of the improved model with the same after incorporating the parameterised D_{st}.

mum velocity ~ 2000 LST and also it is independent of solar flux and magnetic activity. As for temperature is concerned, the stronger the zonal wind and/or the ionization crest, the larger the temperature anomaly and usually it attains its maximum strength, ~1900-2000 LST in consonance with the ionization anomaly strength clearly bringing out the role of ion-drag in the generation of ETWA. This work is done in collaboration with W. R. Hoegy, H. G. Mayr and L. Wharton of GSFC/NASA, U.S.A. and R. Raghavarao.

(R. Suhasini)

Systematic Difference in the Electron Temperature Measurements by Hinotori and Dynamic Explorer-2 Satellite

Systematic differences are observed in electron temperatures (T_e) measured by the US satellite, Dynamic Explorer-2 (DE-2) and Japanese satellite Hinotori. The DE-2 was in elliptical and polar orbit from August 1981 to February 1983 with perigee and apogee around 300 and 1000 km respectively while the Hinotori was in circular and nearly equatorial (inclination 30°) orbit at 600 km altitude from February 1981 to June 1982.

A comparison of T_e values during nighttime measured by both DE-2 and Hinotori and T_e, T_i and T_n values measured by DE-2 itself revealed two main characteristics which are (i) the T_e values measured by DE-2 are lower by at least 100 K than those of T_e measured by Hinotori and (ii) the ion temperatures (T_i) are most often higher than the electron temperatures (T_e), both measured by DE-2.

The observed lower values of T_e and T_i are explained as due to the heat energy flowing from electrons to ions and from ions to neutrals. Further analysis is in progress to examine whether these results can be attributed to any geophysical phenomenon or to the difference in the measurement techniques on the two satellites. This work was done in collaboration with K. I. Oyama of Institute of Space & Astronautical Science, Yoshinodai, Japan and F. Isoda of Yomkohama National University, Hodogaya, Japan and R. Raghavarao.

(R. Suhasini)

Numerical Simulation Results

In view of the recent observation by the Indian MST Radar on the downward drafting of radar plumes associated with the equatorial spread-F (ESF) from the lower altitude F-region (225 - 270 km), an investigation was carried out using the nonlinear numerical simulation model of ESF. The investigation revealed the importance of nonlinear contribution of the background westward electric field during nighttime, in the downdrafting of the radar plumes.

(R. Sekar)

Long Term Ionospheric Changes Over Ahmedabad

Recently there has been concern that the increased concentration of trace gases in the lower atmosphere would result in changes in the upper atmosphere. Following the results that the doubling of carbon dioxide and methane will cool the mesosphere and thermosphere and thereby cause changes in the ionosphere, ionospheric data over Ahmedabad obtained from the radio soundings made during the last four decades were analysed to detect long term changes. Critical frequencies of the E, F_1 and F_2 regions and the peak altitude of the F_2 layer do not show any detectable change.

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

Equatorial Eectrojet - Spatial and Temporal Variability

Results from the rocketborne measurements of the equatorial electrojet currents made from India and Peru and the analyses of the solar quiet day geomagnetic H data at Huancayo and Kodaikanal over a solar cycle period have been utilised to study the longitudinal inequalities in the equatorial electrojet. Using the relationship between the currents measured from rockets and the ground measurements of H and the ionosonde measurements of E-region electron density (peak) it is shown that the average ratio of the current at Huancayo to Kodaikanal is 1.23 and that of the electron velocity 1.31. Thus the longitudinal inequality is caused by the higher electron velocity in the American longitudes. The electric field estimated from velocity is lower in the American longitudes which is in agreement with the recent satellite measurements reported. This work was done in collaboration with Prof. R.G. Rastogi.

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

ESF Irregularities Below the Base of the F-Region

Detailed analysis of the Langmuir probe data obtained from a RH-560 rocket flight conducted from SHAR on 4th October 1988 at 2132 hrs was made during the year. The electron density profile shows the presence of very large scale (~ 24 km) vertical structures below 150 km both during the ascent and descent **(Fig.4.5)** with variations by as much by a factor of 75. Though such large scale structures have been observed in the earlier flights also and such enhancement of the electron density is the largest observed so far. These can possibly be explained in terms of the spatial resonance mechanism. Further it is seen that the region between 150 km to 250 km is not at all smooth but is full of structures with scalesizes ranging from a few km to a few tens of km both during the ascent and the descent. These results, therefore, indicate the effectiveness of the gravity wave winds in producing irregularities right from 100 km altitude to the base of the F-region. Hence there is a need to look again at the convergence rates at altitude above 150 km as these are indicative that even for a low latitude station like SHAR the convergence rates could be very significant.

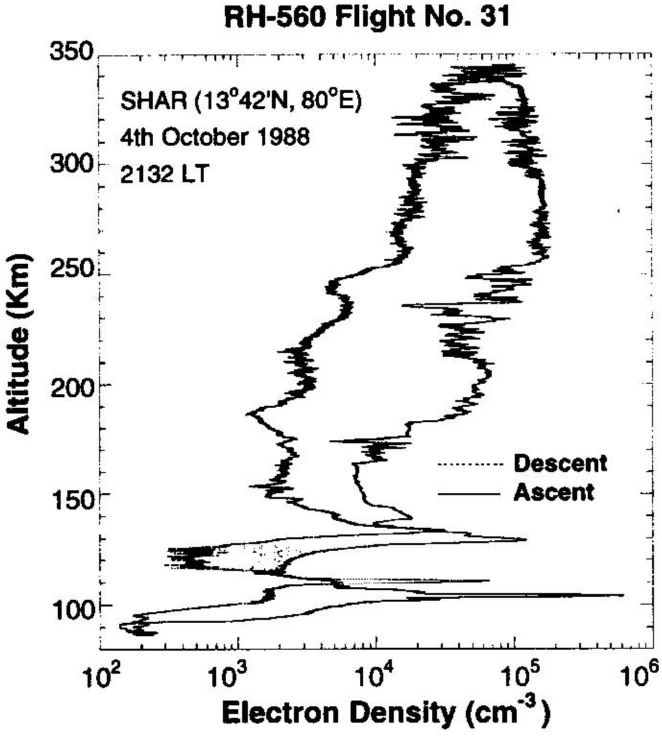


Fig. 4.5 · Electron density profiles during ascent and descent of the RH-560 flight launched from SHAR on 4 October 1988 during fully developed spread-F.

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

PLANETARY/COMETARY ATMOSPHERES

Polar Ion Exosphere of Mars

A model for the study of polar ion exosphere of Mars was developed earlier. This model is extended now to calculate ion temperatures parallel and perpendicular **(Figs.4.6a,b)** to the magnetic field lines between 200 km and 800 km for different exospheric plasma temperatures at 1000 K, 1500 K and 2000 K. The peaks in parallel temperature are inferred to be due to rapid transfer of perpendicular energy to parallel energy via mirror force as found in the polar magnetosphere of Earth. It is also found that the flux, density, mean velocity and temperature of O^+ in the Martian polar exosphere are comparable to those of O^+ polar wind on Earth. Thus, the physical processes of ions escape from the ionosphere of Mars and Earth at high latitude is same inspite of the magne-

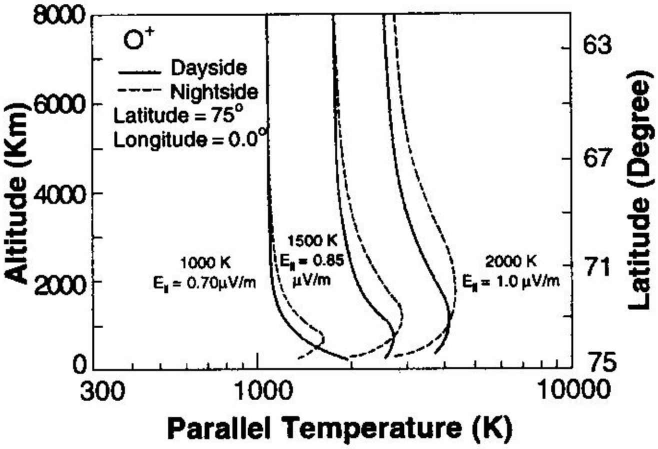


Fig. 4.6a Parallel temperature profiles of O^+ in the dayside and nightside exosphere of Mars at exospheric plasma temperatures 1000 K, 1500 K, and 2000 K for parallel electric fields 0.7, 0.85 and 1.0 μv/m respectively.

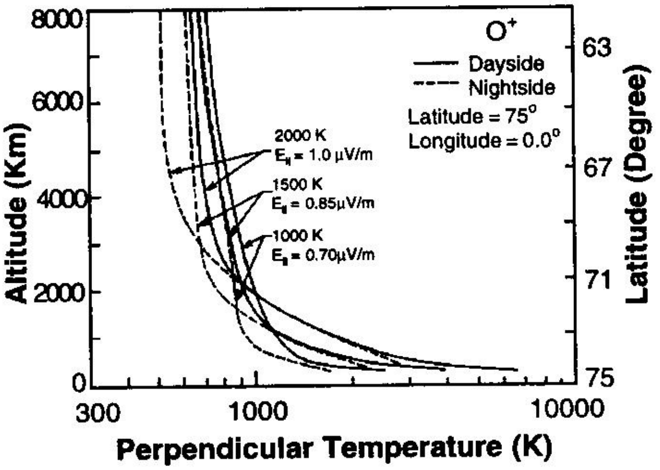


Fig. 6b. Perpendicular temperature profiles of O^+ in the dayside and nightside exosphere of Mars at exospheric plasma temperatures 1000 K, 1500 K, and 2000 K for parallel electric fields 0.7, 0.85 and 1.0 μv/m respectively.

tosphere of Mars is weak and small in comparison with that of the magnetosphere of Earth.

(S.A. Haider)

Chemistry of the Dayside Ionosphere of Mars

The steady state ionospheric model for chemical equilibrium was developed earlier to study the nightside Martian ionosphere. Mars has a weak magnetosphere whose field lines are horizontal throughout most of the dayside ionosphere except in the vicinity of magnetic pole. The horizontal transport of ions along the magnetic fields is more important than the vertical diffusion in the Martian ionosphere. The earlier model is extended now including the loss of ions due to horizontal transport for the study of the chemistry of ions CO_2^+, N_2^+, O_2^+, CO^+, O^+, NO^+, H^+ and N^+ in the dayside Martian ionosphere. Various production and loss processes such as ionization, dissociative ionization, charge exchange and electron dissociative recombination are also included in the model. The calculations are made for solar minimum condition and the results are compared and found to have a good agreement with the experimental data obtained from Mariner 4 and Viking 1 and 2.

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

Cometary Coma

The High Intensity Ion Mass Spectrometer (HIS-IMS) onboard Giotto spacecraft has measured a large number of ions between 10-210 amu in the mass spectra of comet Halley. It is believed that these ions are produced from C, H, N, O and S compounds which evaporate from the icy nucleus due to solar heat as comet approaches the sun. A chemical model has been developed earlier to study the densities of water, ammonia and methane group ions in the coma of Halley's comet. This model is extended now to study the chemistry of C, H, N, O and S compounds for masses ≤ 40 amu. It is found that different sources of ionization, viz., solar extreme ultraviolet radiation, photoelectron and auroral electron of solar wind origin play important role on the chemistry of these compounds. The calculated results are in reasonable agreement with Giotto IMS data.

(S.A. Haider)

LABORATORY ASTROPHYSICS

Photoabsorption Cross Section of SO_2 at 188-220 nm

Photoabsorption cross sections of SO_2 have been measured at different temperatures in the spectral region 188-220 nm. These measurements have been carried out with an accuracy of ± 4% at an instrumental resolution of 0.1 nm at temperatures ranging from 220 to 300 K at an interval of 20 K. The cross section values obtained in the present experiment at room temperature are broadly comparable with one set of data reported in literature but a discrepancy could be noticed when a comparison was made with measurements given by some other set of measurements. It has been found that the measurements carried out in the continuously flowing systems are broadly similar both qualitatively and quantitatively whereas the cross section values reported using closed cell experiments are much higher. The Photoabsorption cross sections obtained at different temperatures revealed that the rate of change of photoabsorption cross section with decrease in temperature increases as a function of incident photon wavelength from 188 to 203 nm and remains constant at 203 to 207 nm and then decreases at larger wavelengths. This type of behaviour seems to favour the suggestion that this entire absorption region could not possibly be identified with a single electronic transition but may consist of two or more transitions.

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

Total Electron Scattering Cross Sections of Carbon Monoxide and Nitrous Oxide

This work is a part of the ongoing research programme which aims to measure total electron scattering cross sections for atoms and molecules at low electron energies using a photoelectron source. An attempt has been made to measure such cross sections for carbon monoxide and nitrous oxide in the energy range from 0 to 10 eV with an accuracy of better than ± 3% and at a fairly high electron energy resolution of about 0.045 eV. Such measurements are of importance in a variety of applications such as the study of planetary atmospheres and interstellar clouds, plasma physics, laser physics, gaseous dielectrics and diffuse-discharge switching. The acquisition of data on both these molecules is complete but work on data analysis is in progress.

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

Radiative Life Time Measurement of NO_2 - Status

The fluorescence excitation spectrum is obtained by photon impact of NO_2 and the fluorescence signal decay curve is measured as a function of incident photon wavelength ranging from 460 to 510 nm and at pressures from 0.1 to 100 m torr. An excimer laser-pumped tunable dye-laser is used to scan incident photon wavelength and a fast photomultiplier and fast sampling digital storage oscilloscope is used to study the total fluorescence of NO_2.

The fluorescence excitation spectrum of NO_2 in the spectral region 465-490 nm has recently been studied **(Fig.4.7a)**. This includes many rotational and vibrational levels superimposed on a broad continuum. The study on pressure dependence of the total fluorescence intensity suggests that self-quenching plays an important role at pressures larger than 5m torr.

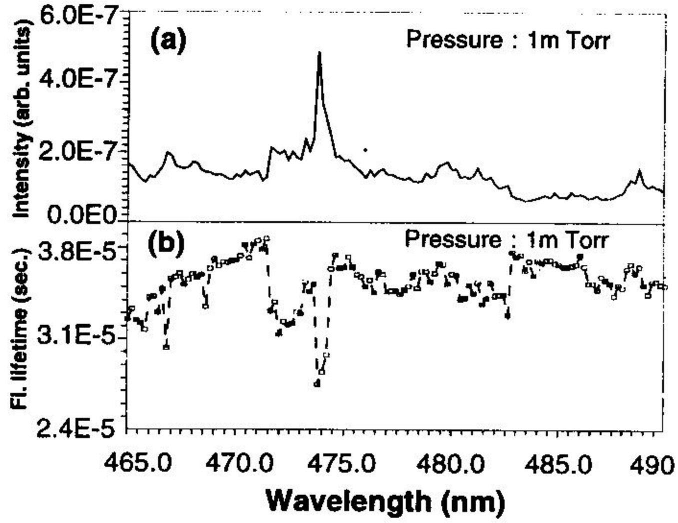


Fig. 4.7 (a) Fluorescence excitation spectrum and (b) Lifetime spectrum of NO_2 at 1mTorr pressure as function of wavelength.

The time-resolved measurements of fluorescence decay curve shows that at low pressure of NO_2 (less than 3m torr), the decay curve is purely exponential. The life time spectrum as a function of incident photon wavelength **(Fig.4.7b)** gives radiative life times varying from 28 to 40 microsec. At pressures larger than 3m torr, the decay is multiexponential and the radiative life times of 1 to 9 and 60 to 130 microsec have been obtained in addition to the life times obtained at low pressures.

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

OCEANOGRAPHY AND CLIMATE STUDIES

The major fields of research of the Oceanography and Climate Studies Area are (i) Palaeoclimate and Palaeoenvironment, (ii) Oceanography and (iii) Hydrology. In Palaeoclimate and Palaeoenvironment Studies, the focus is to retrieve signatures of palaeomonsoon over the past few hundred thousand years from continental and marine archives. Studies of water circulation and particle dynamics in the Arabian Sea and the Bay of Bengal and atmospheric deposition of nutrients on ocean surface are the main topics of research in Oceanography. Issues pertaining to water management and waste water renovation continued to be the emphasis of the Hydrology Programme.

Palaeoclimate and Palaeoenvironment

Speleothems

This year we initiated isotopic and chemical studies on speleothems, a cave calcite deposit, to reconstruct air temperature variations at the time of their deposition. These studies can yield air temperature data for the past few centuries to millennia with a resolution of a few tens of years, which will serve as one of the key boundary conditions to climate models aimed at predicting the monsoon. Samples from Orissa, Madhya Pradesh and Jammu were analysed for this purpose. Stalactites and stalagmites from Gupteshwar, Orissa and Jagdalpur, Madhya Pradesh were subsampled along their growth axis and about 350 samples have been analysed for their stable carbon and oxygen isotope ratios, which show significant variations, ~ 2‰ in $\delta^{18}O$ and ~ 4‰ in $\delta^{13}C$. Radiocarbon age of the Gupteshwar sample is about 4200 years. To establish the chronology of the samples more precisely we hope to explore U-Th dating using TIMS. Efforts are on to collect older samples from other parts of tropical India.

The mean growth rate of speleothems in temperate regions, (such as Jammu) is about 0.1 mm/yr. Assuming this growth rate, we have derived the ambient temperature - time profile (at the time of deposition) in the Jammu region based on oxygen isotope analysis of speleothems. The data seem to show signatures of the Little Ice Age (1675-1715 A.D) and Medieval warming (12th century, A.D). These conclusions await more precise dating of the samples, since there are indications that the sample suffered hiatuses in its growth.

(J.T. Padia, R. Ramesh and M.G. Yadav)

Thar Desert and its Margins

Studies on the DST funded programme on the Quaternary geology and palaeoenvironment of Thar Desert were continued. The mobility rates of transverse dunes in north-west Thar are substantially higher during the past few hundred years compared to those during the preceding 2000 years. This enhanced mobility is attributed to anthropogenic pressure on the eco-system of Thar Desert. The results also indicate that the most recent phase of aeolian sand accumulation ended about 700 years ago. Analysis of various dune profiles provide evidence of the antiquity of dune accumulation extending beyond 100 ka suggesting thereby that the climatic and geological factors were responsible for the aeolian processes in Thar. The results also confirmed our earlier inference of enhanced aeolian activity at ~13ka, suggesting that higher sand accumulations are related to the re-establishment of SW monsoon in the region.

The unconsolidated Quaternary deposits of Mahi basin was investigated to determine the chronology of palaeoenvironmental changes at Raika near Vadodara. The results are in conformity with our earlier findings on a similar horizon from River Sabarmati, suggesting thereby a regionally extended soil forming episode at ~ 50 ka and the onset of aeolian accumulation at ~10ka.

A new approach to analyze optically stimulated luminescence (OSL) data was developed to date sediments that do not receive the full quantum of predepositional daylight exposure to erase their TL signal. This method, termed as *ultimate partial bleach method*, allows optimization of illumination flux and spectra to an arbitrarily desired level. The method has been successfully tested on sediments from a wide variety of depositional environments.

The work on Monte-Carlo simulation to determine the configuration of experimental data set in Luminescence dating that would provide an optimum bound on the experimental error was continued. It was inferred that a data set of ~ 42 individual measurement points, clustered and spaced exponentially upto a dose value of 6 times the equivalent dose would provide an optimally lower error within a reasonable irradiation time schedule.

During the past year, two automated TL/OSL analysis systems were installed to increase the analytical capability of this laboratory.

The above studies were carried out in collaboration with the co-investigators in Thar Desert Programme from CAZRI, Jodhpur; Deccan College, Pune; Delhi University, Delhi; BARC, Bombay and IIT, Bombay. Topical collaborations with scientists from M.S.University, Baroda; Max-Planck Institute for Nuclear Physics, Heidelberg and Institute for Applied Physics at Freiberg, Germany were also made.

(D.Banerjee, C.Felix, N.Juyal, J.V. Thomas, A. Kailath, M.S.Rao and A.K.Singhvi).

Palaeoceanography Studies using Arabian Sea Sediments

Efforts to retrieve palaeoceanographic and palaeoenvironmental records stored in the continental margin sediments of the Arabian sea were continued. Measurements of oxygen isotopes and chemical elements (Mn, Sr, Ba, V) that are indicators of biological productivity in surface waters and redox conditions in sediments have been completed in a long gravity core SS 3268G2 (12°31' N; 74°9'E in 370 m water depth). Preliminary ^{210}Pb measurements yield ~ 1 mm/yr for the sediment accumulation rate, more precise estimates based on ^{14}C measurements in foraminifera by AMS is currently underway (at NSF Arizona AMS Facility, USA). This study is aimed to provide a better understanding of the factors influencing the distribution of various elements in the sediment pile and their relation to depositional environment.

To extend the palaeoclimatic/palaeoceanographic studies to the other adjacent seas of India, a cruise of FORV Sagar Sampada was undertaken to the Bay of Bengal during February-March , 1997. A large number of sediment core samples were collected for deciphering past climatic/oceanographic changes based on records contained in them.

(R. Agnihotri, M. Dixit, K. Dutta, S.Krishnaswami, A. Sarkar, B.L.K. Somayajulu and D.N. Yadava).

Palaeogene Sequence from Kutch

Stable isotope analyses have been carried out on rocks and fossils of the Palaeogene carbonate-clastic sequence of the Kutch area in western India to assess the environmental conditions at the time of their deposition. Isotopic, lithological and palaeontological data indicate that sedimentation in this region started in the early middle Eocene (Lutetian) in lagoonal basins. A variety of large benthic foraminifera named Assilina was the dominant species in this environment. The basins were later cut off by the oscillatory withdrawal of the sea, which trapped large amounts of organic matter, degradation of which produced some bioclastic limestones with extremely depleted carbon isotope values. The oxygen isotope values of the limestones suggest a significant contribution of fresh water into these lagoons. The geological setting of these limestones suggests that they were deposited in a warm, humid climatic milieu a part of the global warm humid belt during the Lutetian. This work was carried out in collaboration with Dr. A. Sarkar of the Indian School of Mines, Dhanbad.

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

Enigmatic Deposits from Gondwana Basins of Eastern India : Freshwater Stromatolites or Travertines?

Talchir Formation constitutes the lowermost unit of the Gondwana sequence in Eastern India. Oxygen and carbon isotope studies of calcareous nodules of this formation have indicated glacial melt as the source water for the calcareous cement and probable existence of a megamonsoonal circulation causing extreme fractionation during precipitation.

During the last year we found a large number of unusual objects comprising of coarsely crystalline limestone, occurring in thick beds of shale in these basins and resembling the features of algal stromatolites in the Otavi Series, Southwest Africa and in Anatarctica.

Stable isotope analyses of these algal stromatolites(?) from near Bedasar village (20°52'N; 85°4'E) show that samples showing least alteration have δ^{18}O values ranging from -10‰ to -20 ‰ and δ^{13}C values ranging from -10‰ to -15 ‰. The low δ-values suggest that these stromatolites were precipitated in a fresh water lake. The isotopic composition of Sr measured in these samples also attest to their freshwater origin. The stromatolites occur above the stratigraphic level of calcareous nodules which were analysed earlier and showed evidence of glacial origin. The increase in δ^{18}O value of these algal objects relative to those of the nodules clearly indicate a climatic amelioration in the later part of the Talchir glaciation, which was warm enough to support the growth of the algae. This work was done in collaboration with Prof. A.Chakraborty of IIT, Kharagpur.

(S.K. Bhattacharya, P. Ghosh, R.A. Jani and J. R. Trivedi)

Oceanography

Water Circulation in the Arabian Sea

A programme to study the time scales of water circulation in the Arabian Sea and the air-sea exchange fluxes of CO_2 was initiated 3-4 years ago. In this connection, we collected a total of 120 samples from eight profiles for radiocarbon measurements most of which have been completed. Estimate of the air-sea exchange of CO_2 relies on the measurement of temporal variations in the inventory of "bomb" ^{14}C in the water column. To determine these variations, three GEOSECS stations were reoccupied after a gap of 16-17 years. In addition to radiocarbon, measurements of total carbon-dioxide (ΣCO_2) were also made. Typical radiocarbon and ΣCO_2 profiles at one of the reoccupied GEOSECS stations are given in **Fig 5.1**. The "bomb" ^{14}C inventory measured during 1995 shows a small increase compared to that in 1978 resulting from the transfer of bomb ^{14}C from the atmosphere to the ocean surface water. Preliminary estimates of CO_2 exchange rates are in the range of 7-15 moles/m^2/yr. Detailed analysis of the data is under way. On the technical side, we have streamlined all the procedures and shown that Δ^{14}C can be routinely measured from 100 ℓ of sea water to a precision of ± 5‰. These studies are currently being extended to the Bay of Bengal.

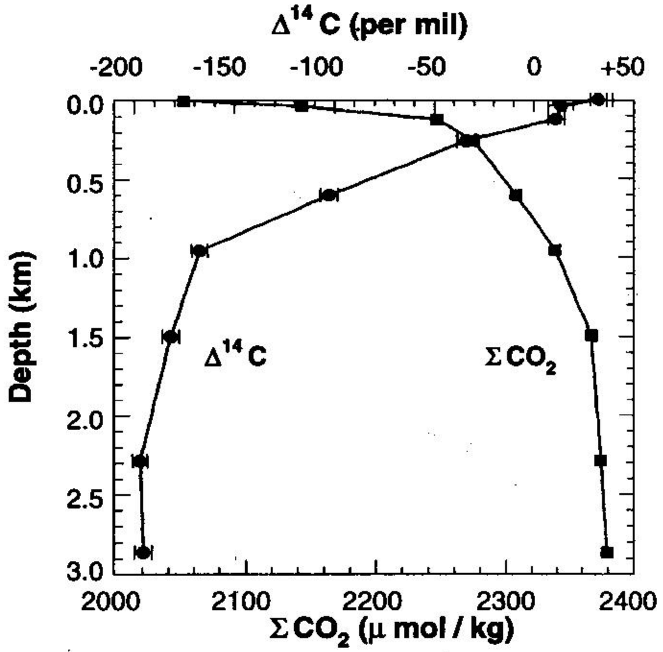


Fig.5.1 Radiocarbon and ΣCO_2 depth profiles from station SS-132/3271 (13°N 64.5°E) from the Arabian Sea.

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

Particulate and Carbon Export Fluxes Derived from ^{234}Th

Attempts to use ^{234}Th as a tracer for estimating particle and carbon export fluxes from the upper 100m of the Arabian Sea were continued as a part of the national JGOFS programme. The particle export fluxes computed from ^{234}Th export range between 1900 to 3300 mg/m^2/d during winter months, significantly higher than those measured directly using free-floating sediment traps. These differences have led us to undertake a time series sampling approach during February 1997 (winter season) to investigate further the cycling of various components of particulate matter and ^{234}Th in the upper Arabian Sea. A total of eight vertical profiles were collected for the measurement of ^{234}Th and related parameters. These data will be used to relate particulate ^{234}Th and carbon export fluxes out of the euphotic zone.

(R. Rengarajan and M.M. Sarin)

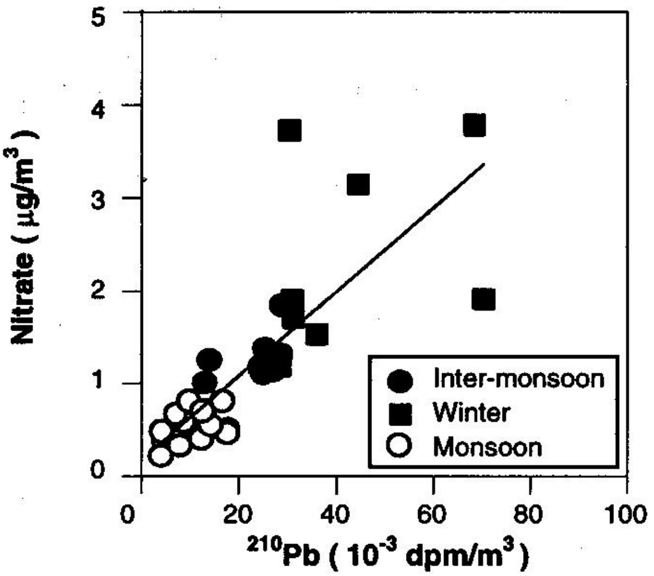


Fig. 5.2a. Scatter diagram of NO_3 - vs - ^{210}Pb concentrations in the air over the Arabian Sea during three seasons. Measurements were made as a part of the national JGOFs programme

Nitrate, Non-sea-salt Sulphate and ^{210}Pb over the Arabian Sea

Study on the atmospheric deposition of nitrate (NO_3) non-sea salt (NSS) sulphate and ^{210}Pb to the Arabian Sea was continued during the past year to assess the role of atmospheric supply of NO_3 in contributing to "New Nutrients" to surface waters **(Figs. 5.2a,b)**. The concentration of ^{210}Pb (a tracer predominantly of continental origin) in marine air shows a positive correlation with NO_3, implying that both NO_3 and ^{210}Pb are associated with similar types of aerosols. Using $NO_3/^{210}$Pb ratio and the measured ^{210}Pb deposition flux in the study region the NO_3 deposition flux to the surface waters is estimated to be ~ 1000µg/m^2/d. The co-variation trend between NSS SO_4 and NO_3 is significantly different for the winter and monsoon samples, reflecting differences in their source functions during different seasons. To characterise these better, a large number of aerosol samples have been collected during the winter of 1997 from the Arabian Sea, the analysis of which are currently underway.

(S. Krishnaswami, R.Rengarajan and M.M. Sarin)

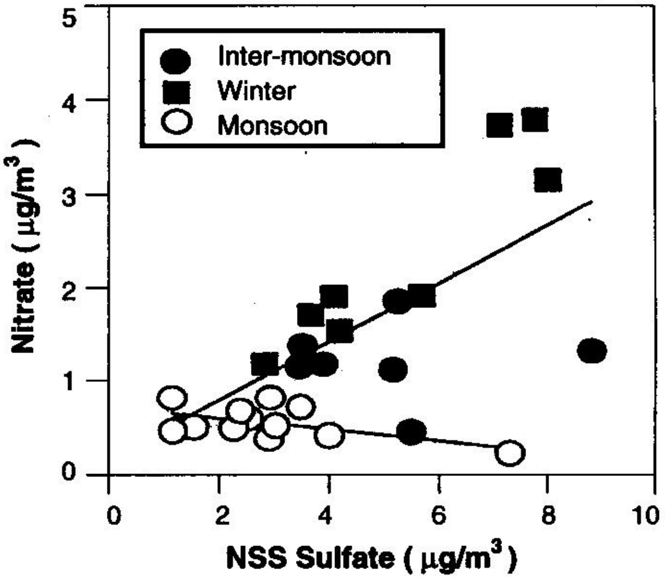


Fig.5.2b. Scatter diagram of nitrate-vs-NSS sulfate during three seasons in air over the Arabian Sea.

Study of Indian Carbonatites

The stable isotope systematics of major carbonatite bodies in India were reported last year. This year the radiometric dating of two major complexes, Amba Dongar in Gujarat and Sung Valley in Meghalaya were carried out. Three alkaline rocks and a phlogopite separate from the carbonatite body of Amba Dongar yielded good Ar-Ar plateau ages **(Fig. 5.3)**, with a mean value of 65.0 ± 0.3 Ma. Two phlogopite separates from carbonatites from Sung Valley have a mean age of 107 ± 1 Ma. These ages are consistent with the plume-origin hypothesis for the formation of Cretaceous alkaline carbonatite complexes of India. In addition Rb, Sr concentrations and ^{87}Sr/^{86}Sr ratios were measured in a number of samples from both complexes. The results show that carbonatites have a fairly uniform ratio of ^{87}Sr/^{86}Sr. For the Amba Dongar samples the value is 0.7060 ± 0.0003 while for the samples from Sung Valley, it is 0.7050 ± 0.0005. These results along with the stable isotope data reveal that the carbonatites from either complex do not have any significant crustal contamination.

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

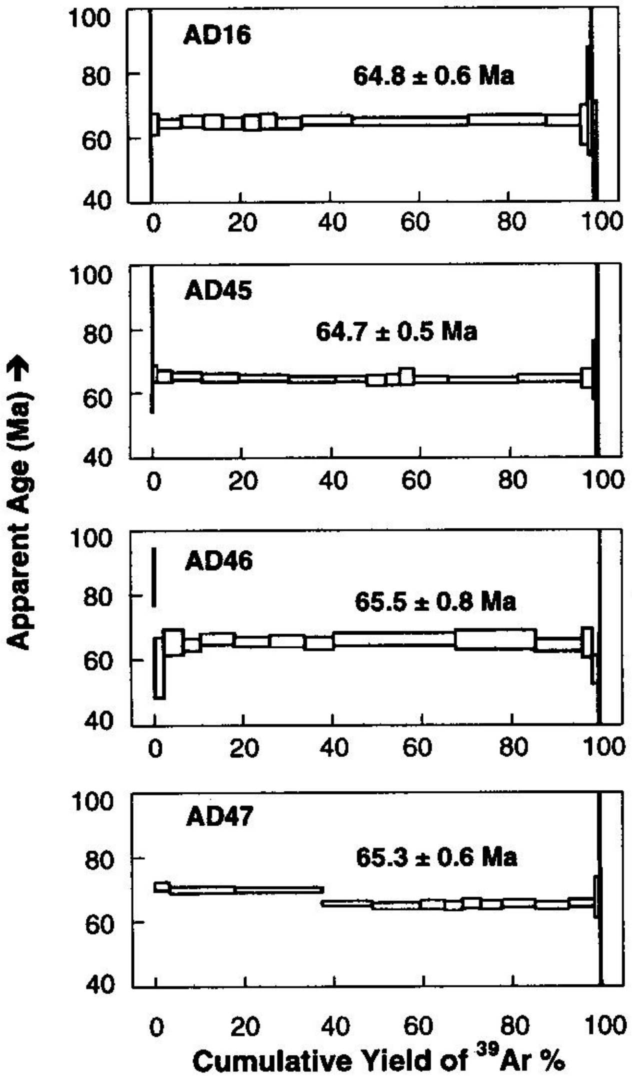


Fig.5.3 Age spectra of Amba Dongar alkaline rocks (AD16, AD45 and AD47) and a phlogopite separate from a carbonatite (AD46) with their plateau ages.

Sr Isotopes in Carbonates of the Lesser Himalaya

A detailed study of the chemical composition and Sr, O and C isotope systematics in carbonate exposures from the Lesser Himalaya was undertaken to determine their role in contributing to the highly radiogenic Sr isotope composition of the source waters of the Ganga and the Indus. Our results show that the Sr isotope composition of many carbonate outcrops from the Lesser Himalaya are more radiogenic than that of coeval sea water suggesting that their Sr isotope composition has been modified significantly by post depositional alteration processes. Comparison of (Sr/Ca) and ($^{87}Sr/^{86}Sr$) in the carbonates and in source waters lead us to conclude that though some of the carbonates from the Lesser Himalaya can serve as source of radiogenic Sr for streams on a regional scale, on an average they are unlikely to be a major contributor for the high radiogenic Sr composition of source waters of the Ganga and the Indus.

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

Hydrology

Municipal Waste Water Renovation Using Sabarmati Riverbed Aquifer in Ahmedabad - A Pilot Study

The pilot study for the renovation of municipal waste water through soil-aquifer-treatment system in the Sabarmati riverbed at Ahmedabad was continued to assess in greater detail the quality of effluent water. During 1996, a total of 228 x 10^3m^3 primary settled sewage entered the pilot system. A total of 138 x 10^3m^3 of renovated waste water was pumped out, yielding an average output of about $1000m^3$/day. Analysis of the performance data of the SAT system showed a reduction in the organic pollutants (COD, BOD and SS) by about 90%; in the nutrients (TKN, NH_2-N, PO_4-T, PO_4-O) 50% to 95% and a removal efficiency for oil and grease and detergents ~ 45%. The NO_3-N, however, increased by ~ 40 %. This pilot study demonstrated that primary settled sewage could be renovated by SAT process to meet the effluent quality standards for unrestricted irrigation and groundwater recharge at a high hydraulic loading rate of 30m/yr. The programme was carried out in collaboration with P. Nema of NEERI.

(S.K. Gupta)

National Radiocarbon Facility

The radiocarbon laboratory of the group, in addition to pursuing programmes in palaeoclimates continued to provide chronology to a number of archaeological/geological samples received from various institutions in the country. This year about 45 samples have been analysed for determining their radiocarbon ages. Some of the important findings are :

Chalcolithic culture from Balthal, a site in Udaipur, is dated to occur during 3800 to 5800yrs BP. From Tamilnadu a megalithic habitational site shows age of 2000yrs BP. based on charcoal dating. Harappan site 'Rojdi' shows another layer of artifacts around 3600yrs BP. We have dated three samples from Nigerian archaeological site. Iron working (furnace activity) is found during 650yrs BP from this site.

Soil samples from Maharashtra have been dated to know the time elapsed since the deposition of basaltic alluvium on which they have formed. A soil layer between 126 to 145cms depth from Amravati gives age of 4400yrs BP whereas a layer between 16-41cm from Wardha is dated at 1600yrs.

(Sheela Kusumgar and M.G. Yadava)

SOLAR SYSTEM AND GEOCHRONOLOGY

The scientific programmes of the group relate to the origin of the solar system and planets, origin and evolution of meteorites, geochronology of the Himalayas and the Indian lithosphere and study of the geological boundaries and their causes.

Search for Extinct ^{36}Cl in Allende Meteorite

Recently we detected excess ^{36}Ar (over and above the trapped and cosmogenic components) in the primitive carbonaceous chondrite Efremovka, which is attributed to the decay of the extinct nuclide ^{36}Cl, formed in stellar nucleosynthesis and injected into the early solar system just before the formation of the meteorite. Earlier efforts to find evidence for extinct ^{36}Cl in the Allende meteorite, which belongs to the same class as Efremovka, were not fruitful. Since halogen-rich primary phases are potential sites to host extinct ^{36}Cl, we have measured Ar and other noble gases in the halogen rich chondrule 3509 from Allende to look for signatures of extinct ^{36}Cl.

The Xe in this chondrule is almost pure ^{129}Xe (from decay of ^{129}I) with ^{129}Xe/^{132}Xe ~1200. The ^{36}Ar/^{38}Ar ratios ranged between 1.98 to 27.0. The release pattern of ^{36}Ar, ^{36}Ar/^{38}Ar and ^{129}Xe are given in **Fig. 5.4.** The peak release of ^{36}Ar and the ratio ^{36}Ar/^{38}Ar occur at 800°C, while that of ^{129}Xe occurs at 1200°C indicating that the excess ^{36}Ar is related to ^{36}Cl (either *in situ* produced or extinct) and that Cl and I are not sited in the same mineral phase. Our results show that almost the entire ^{36}Ar excess can be accounted for by *in situ* production by (n, γ) reaction on ^{35}Cl. We obtain upper limits of ^{36}Cl/^{129}I < 0.23 and ^{36}Cl/^{35}Cl < 6x10^{-9}, compared to the corresponding values of 190 and 1.4x10^{-6}, respectively for Efremovka. In summary we do not find clear evidence for the presence of extinct ^{36}Cl in this chondrule. The upper bound for initial ^{36}Cl/^{35}Cl would suggest elapse of at least 2 Ma between the formation of Efremovka CAI and this Allende chondrule. This work has been carried out in collaboration with the California Institute of Technology, U.S.A.

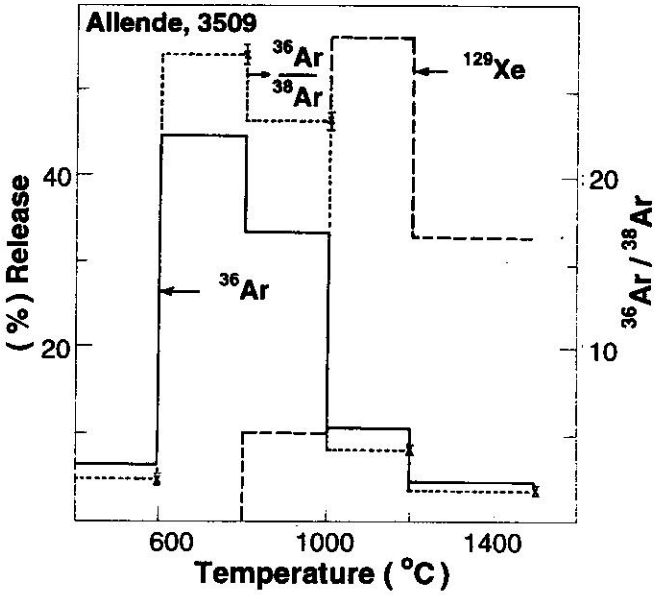


Fig.5.4 Release pattern of ^{36}Ar, ^{129}Xe and ^{36}Ar/^{38}Ar for the Allende chondrule 3509.

(S.V.S. Murty)

Short-lived Nuclides Present in the Early Solar System

The presence of short-lived nuclides in the early solar system is generally attributed to the injection of freshly synthesized material from a specific stellar source to the protosolar cloud just prior to its collapse. This event is perhaps responsible for triggering the collapse of the protosolar cloud as well. However, it has also been proposed that some of the short-lived nuclides present in the early solar system (including ^{26}Al and ^{41}Ca) could have been produced by energetic particle interactions within the protosolar cloud or later in the solar nebula. Simultaneous study of ^{26}Al and ^{41}Ca may allow us to narrow our choice of possible origins of these nuclides. We have, therefore, carried out such a study in small domains (~10micron) of refractory hibonite ($Ca[Al,Mg,Ti]_{12}O_{19}$) grains present in three primitive meteorites using an ion microprobe.

We have made significant improvement in the analytical procedures for K isotopic measurement and the results obtained by us **(Fig.5.5)** indicate correlated presence and absence of the now-extinct short-lived nuclides ^{26}Al and ^{41}Ca at the time of formation of these refractory grains in the early solar system. This suggests that ^{26}Al and ^{41}Ca originated from a common source and followed the same pathways in the solar nebula before their incorporation into the analyzed hibonites. This is not compatible with the energetic particle irradiation scenarios as they can not coproduce these nuclides in the right proportion to match their observed abundances. Injection of freshly synthesized material from stellar sites to the protosolar cloud, just prior to its collapse, remains the most plausible source of these and several other short-lived nuclides in the early solar system. This work was carried out in collaboration with Enrico Fermi Institute, Chicago, USA.

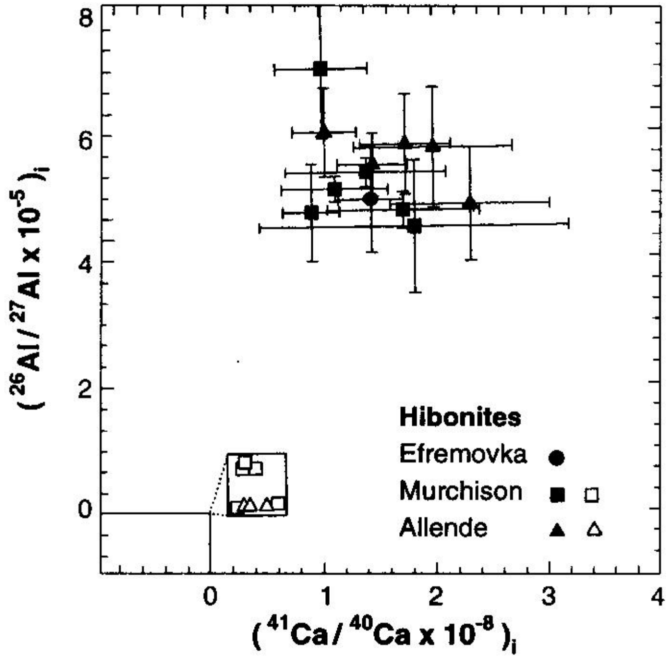


Fig.5.5 Initial abundances of ($^{26}Al/^{27}Al$ and $^{41}Ca/^{40}Ca$) in hibonites from three primitive meteorites Efremovka, Murchison and Allende. Initial ratios greater than zero indicate presence of live ^{26}Al and ^{41}Ca at the time of formation of the hibonites. Two groupings are evident indicating correlated presence and absence of these two nuclides in the hibonites.

(J.N.Goswami and S.Sahijpal)

Production of Short-lived Nuclides by Solar Energetic Particles in the Early Solar System

The possibility that some of the short-lived nuclides in the early solar system could be produced by energetic particles from an active early Sun has been proposed. However, most of the studies on the production of these nuclides by solar energetic particles (SEP) are inadequate as they made ad-hoc assumptions regarding the energy spectra of SEP and ignored production by alpha particles. The recent evidence obtained by us for the presence of the short-lived nuclides ^{41}Ca and ^{36}Cl in the early solar system led us to calculate production of these two nuclides along with ^{26}Al and ^{53}Mn by SEP from an active early Sun.

We consider both the standard representations of the SEP spectra, a power law in kinetic energy ($dN/dE = const.\ E^{\gamma}$) and exponential in rigidity ($dN/dR = const.\ exp[-R/R_0]$). The spectral parameters γ and R_0 are assigned values to cover a wide range of spectral shapes. The alpha particle to proton ratio was kept variable. Appropriate reaction cross-sections have been considered and we take nebular dust of CI composition as the target material. All the calculations are based on the following flux normalization : $N(E > 10 MeV) = 100$ protons $sec^{-1}cm^{-2}$, which fairly well represents the recent average SEP flux.

Based on the production rates for the different nuclides we infer the flux enhancement factor, over the long-term averaged SEP flux, necessary to match the initial abundance of these nuclides in the early solar system. The enhancement in SEP flux as a function of irradiation duration is shown in **Fig.5.6** for spectral index $\gamma = 3$. It is obvious that no irradiation time/enhancement factor combination can lead to co-production of ^{26}Al with any of the other three nuclides that will match the meteorite data. Co-production of ^{41}Ca, ^{36}Cl and ^{53}Mn appears to be likely if the enhancement factor is $>10^4$ and the irradiation time scale is close to a million years. The lower initial value for ^{53}Mn/^{55}Mn inferred from some of the recent experiments can be generated even with a much lower enhancement factor for similar irradiation duration.

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

Ancient Martian Atmospheric Composition from ALH 84001

Martian atmospheric gases were first identified in the meteorite EET 79001. Since the crystallisation age of EET 79001 is ~180 Ma, it represents the atmospheric composition of Mars for the recent past. The Sm-Nd age of 4.56Ga and Ar-Ar age of 4Ga of ALH 84001 establish its antiquity and any atmospheric component found in this meteorite will represent the Martian atmosphere of ancient era. This provides an opportunity to delineate the atmospheric evolution. We have identified the isotopic signatures of noble gases and nitrogen in ALH 84001 having, ^{20}Ne/^{22}Ne=10.6, ^{129}Xe/^{132}Xe=2.24 and δ^{15}N=46‰. Comparing these isotopic ratios as well as the elemental ratios to the corresponding values obtained from EET 79001, we find an additional component besides the two normal components representing the Martian atmosphere and the solid Mars. The additional component has isotopic signatures of martian atmosphere, but a fractionated elemental pattern showing enrichment of heavy noble gases, brought about most probably by aqueous processes during the early evolution of Mars.

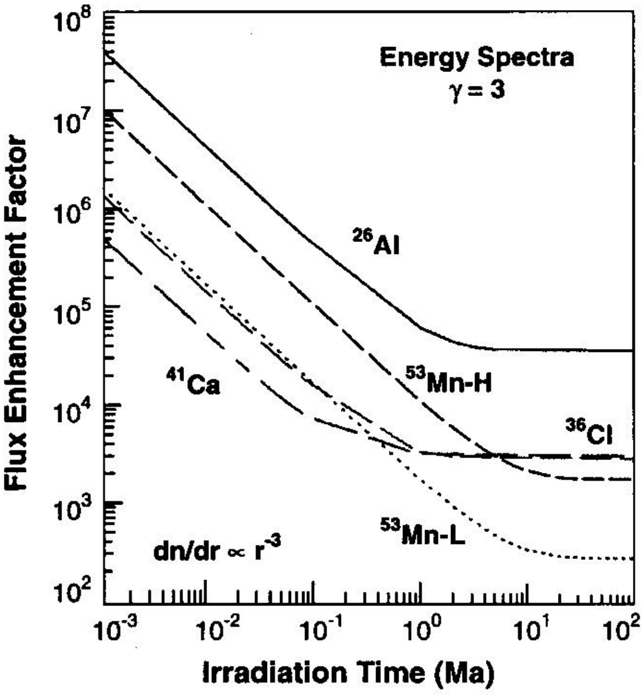


Fig. 5.6 Flux enhnacement factor for solar energetic particles (SEP) from the early Sun, compared to the contemporary flux, necessary to match the abundance of the short-lived nuclides observed in primitive meteorites, plotted as a function of SEP irradiation time.

The noble gas data obtained from ALH 84001 allow us to make the following inferences on the evolution of the Martian atmosphere: (a) Xe isotopic composition as well as the amounts of Xe and ^{36}Ar in Martian atmosphere were completely evolved by ~ 4Ga and remained almost unchanged to the present, (b) The radiogenic ^{40}Ar has not been completely degassed into the atmosphere at 4Ga and (c) Nitrogen has been lost in a continuous process, leading to an increase in the ratio of ^{36}Ar/^{14}N as well as the δ^{15}N in the present Martian atmosphere, as compared to 4Ga ago. These inferences are consistent with the predictions of the most successful hydrodynamic escape model for the evolution of the Martian atmosphere.

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

Piplia Kalan Eucrite : Chemical and Isotopic Studies

Two stones weighing approximately 25 and 10kg fell near Piplia Kalan Village in the Pali district of Rajasthan on June 20, 1996. Comprehensive analysis of this meteorite was carried out and it was found to belong to the rare group of eucritic meteorites. The multi-prong studies carried out on this meteorite include (i) particle tracks, (ii) noble gases, (iii) major and trace element chemistry, (iv) computation of probable orbit, (v) petrographic and mineralogic studies and (vi) measurement of cosmogenic radioisotopes.

The bulk chemical composition, elemental ratios

(FeO/MnO, K/La), the inter-elemental correlations (Yb vs Yb/Sc, CaO vs FeO(FeO+MgO) and Ti vs Mg) and REE patterns clearly place Piplia among the group of noncumulate eucrites. Presence of several lithologies and texturally different matrix and clasts indicate that it is a breccia with diverse components.

The track density, radionuclide and cosmogenic rare gas data ($^{22}Ne/^{21}Ne = 1.14$), being close to the expected production, indicate that the Piplia Kalan had a simple one stage exposure history. Its preatmospheric mass was small ~175 kg and it entered the Earth's gravitational field with a geocentric velocity of 17±1 km/s. The orbital parameters $a = 2.5$ AU and $i = 7.5^\circ$ suggest that it originated in the inner asteroidal belt, consistent with 4Vesta as its parent body. The exposure age of 23 Ma falls within a known cluster of eucrite exposure ages.

The thermal history of the eucrite Piplia Kalan is quite complex as indicated by the radiogenic ages. The Pu-Xe age (4.56 Ga) indicates that it formed early, but younger K-Ar and U-He ages indicate impact events leading to thermal metamorphism much later in its history, but these events did not disturb the Pu-Xe system.

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

Nitrogen in Muong Nong Tektites

Noble gas studies in tektites have shown that their composition is air-like proving their terrestrial origin. The excess Ne (and He in some cases) are shown to be due to later inward diffusion from ambient air during geologic time. But surprisingly no efforts were made so far to look at the isotopic composition of nitrogen (the major component of earth's atmosphere) in tektites. We started an investigation of N in tektites and so far measured 3 samples of Muong Nong tektites. They have N content ranging from 0.3 to 1.3 ppm with $\delta^{15}N$ in the range of 8 to 17‰, much heavier than air. The release pattern indicates the presence of two N components, one with $\delta^{15}N = 20‰$ and the other with $\delta^{15}N = 5‰$. While peak release of N occurred at 1100°C, the peak release of Ar, Kr, Xe of pure atmospheric origin occured at 1400°C. Also the $N/^{36}Ar$ of the tektite is 2 to 20 times higher than the air value.

These results suggest that a major proportion of N in Muong Nong tektites is non-atmospheric in origin and should come from the source rock, due to incomplete degassing in the process of tektite formation. The source rock of tektites has been shown to be of sedimentary type. The $\delta^{15}N$ of sedimentary rocks is typically in the range of 5 to 17‰ depending on their provenance and metamorphic grade. This $\delta^{15}N$ might further increase due to isotopic fractionation in the process of tektite formation. The higher $\delta^{15}N$ values of upto 20‰ in the M.N. tektite samples are consistent with the picture that most of the N in them is a remanant from the original source rock.

(S.V.S. Murty)

Proterozoic Basic-acidic Bimodal Magmatism in a Rift Tectonic Environment in Garhwal Himalaya

A large gabbroic body is located along the Chail thrust in Kepsar-Thayeli area in Garhwal Himalaya. Geochemical and petrological studies indicated it to be a part of the feeder chamber for a large Precambrian basaltic province.

We studied rocks of this gabbro and obtained a whole rock Rb - Sr isochron age of 1989±117 Ma having initial $^{87}Sr/^{86}Sr$ of 0.7016±0.001. This age coincides with several age cluster (1800-2000 Ma) assigned to the granitic gneisses and granitic augen gneisses within the Main Central Thrust (MCT) zone at various locations in this region. Such coincidence of age for basic and acidic rocks is being reported for the first time in Himalaya. However, the age for this gabbroic body is not in conformity with the suggested age of 2.52±0.46 Ga for the Berinag and Bhawali mafic volcanics of Garhwal and Kumaun Lesser Himalaya based on Nd isotopic studies.

The possibility that this gabbroic body probably represents a large magmatic event and the coincidence of Paleo-Protozoic ages for this gabbro and various granitoids from this region opens the possibility of Proterozoic basic-acidic bimodal magmatism in a rift tectonic environment. Such bimodal magmatism is quite common in rift related Phanerozoic continental flood basalts. This observation probably implies similarities in petrogenic and tectonic processes at least in Proterozoic and Phanerozoic times.

(J.R.Trivedi)

Sr isotope Systematics of Amba Dongar Alkaline Rocks : Evidence for Liquid Immiscibility and Wall-rock Assimilation

Sr isotopic measurements in alkaline rocks (nephelinites and phonolitic nephelinites) and Bagh sediments (limestones and sandstones) were analysed and initial $^{87}Sr/^{86}Sr$ values were calculated using an age of 69 Ma for this complex. Bagh sandstone yield a ratio of 0.7567 (at 69 Ma BP) and Sr concentration of 68 ppm, while limestones showed variable ratios and concentrations reflecting Sr isotopic heterogeneity in them. These results cannot be explained in terms of mixing of specific components or assimilation following fractional crystalisation (AFC). A magmatic process other than simple binary mixing and AFC is probably responsible.

We considered the Sr-isotopic effect of carbonate-silicate liquid immiscibility on alkaline rocks, believed to be an important process involved in carbonatite generation. For this we modified the AFC model for simultaneous crystallization and separation of an immiscible carbonate melt from a silicate melt which is assimilating the country rocks (ACLI model hereafter). Model curves were generated taking sandstone and limestone as assimilants **(Fig. 5.7)** and it was found that these curves fit the alkaline rock trend. It is probable that both variety of wall rocks, limestones and sandstones, have contaminated the parental alkaline magma. Therefore, to estimate the maximum percentage of assimilation, an average assimilant ($^{87}Sr/^{86}Sr = 0.7507$ and Sr = 73ppm) was considered. It was observed that the ACLI model could explain the isotopic variation with maximum 1.6% of assimilation. This implies that the liquid immiscibility of carbonate melt from an alkaline silicate melt played a significant role in the evolution of this complex.

From the present study it is found that the alkaline rocks and carbonatites of Amba Dongar complex are genetically related, and the parent carbonated alkaline magma of these rocks have evolved through liquid immiscibility and wall rock-assimilation.

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

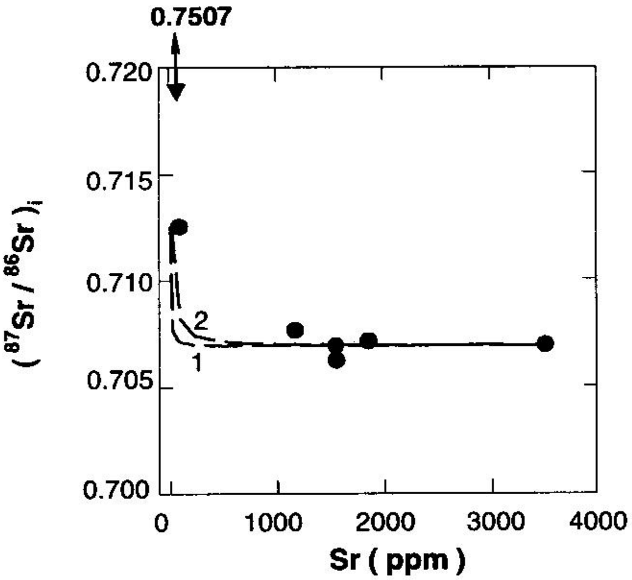


Fig.5.7 ACLI model curves, when the assimilant is an average country rock (73ppm, 0.7507) represented as a solid triangle for different distribution coefficients (D)

Archean Component in the Bundelkhand Massif, Central India

The Bundelkhand massif is a composite granite-gneiss province occupying an area of about 26,000 km^2 in the central portion of the Indian shield. The bulk of the Bundelkhand massif comprises of various phases of undeformed granitoids with relicts of gneisses, banded iron formations (BIF), meta sediments and mafic and ultramafic suites. The massif has a complex geological history of evolution as demonstrated by the contrasting litho-units and polyphase deformational events, typical of many Archean-Paleoproterozoic cratons.

We have determined radiometric $^{207}Pb/^{206}Pb$ ages of individual zircons from the Bundelkhand massif by an ion microprobe. Samples from various major litho-units viz., the gneiss, hornblende-, biotite- and leuco-granitoid are included in this study. The initial results obtained from this study provides the first conclusive evidence for the presence of Archean crustal component within this massif. 3.1 Ga old zircons occur as xenocrysts in a sample of gneiss from Lalitpur having a minimum formation age of 2.5 Ga. Another sample of a highly deformed gneiss from

Babina has a well defined age of 2.7 Ga. Emplacement of hornblende granitoid and biotite granitoid took place in quick succession during Paleoproterozoic. The geochronological data confirm the suggestion, based on geochemical studies that the gneisses and the granitoids in this region represent typical Archean and post-Archean components, respectively. This work is carried out in collaboration with the Wadia Institute of Himalayan Geology, Dehradun.

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

^{40}Ar/^{39}Ar Study of the Himalayan Mafic Volcanics : Evidence for Reactivation of Pre-existing Faults during Later Inversion

Cooling ages determined on the Himalayan rocks have invariably been ascribed to exhumation resulting from thrusting along the Main Central Thrust (MCT). This puts a constraint for suspecting an age not related with the collision process. This may be largely true for the Higher Himalayan rocks, whose post-collision uplift is undisputed. The Lesser Himalayan belt, however, appears to have undergone a different history where older cooling ages may not necessarily be anomalous; indeed cooling ages as old as Proterozoic have been reported from Nepal sector of the Lesser Himalaya. The sample analysed by us cover a wide time range from 315 Ma to 19 Ma. These ages are well reflected in the stratigraphic record and relate to known tectonic events, both pre-orogenic and orogenic. These ages support geomorphic and stratigraphic consideration which favour an older exhumation history for Lesser Himalaya relative to the Higher Himalayas. The most significant result of the study is that it provides empirical data support for fault reactivation model of Himalayas in general and for the Foreland basin in particular. This is a collaborative project with the Wadia Institute of Himalayan Geology, Dehradun.

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

Application of Cosmogenic ^{10}Be for Characterising Natural Weathering Processes

^{10}Be, a radionuclide with a half-life of 1.5 my, is continually produced on the earth by nuclear interactions of cosmic rays: (i) in the earth's atmosphere, and (ii) in terrestrial surficial materials containing oxygen, and can be easily detected using AMS (accelerator mass spectrometry). We have explored new applications of ^{10}Be produced initially in the atmosphere, and subsequently mixed with surficial materials, for characterising natural weathering processes. Chemical weathering is an ubiquitous process on the earth's surface resulting in production of soils, which contain a valuable paleo-record of earth's climate. We chose detailed ^{10}Be studies of seven soil profiles of (a) different types of ages (0 - 5) my, resulting from *in-situ* rock-weathering, and (b) a large number of loess-paleosol sequences from five sites in the Chinese loess plateau, weathered principally during wet periods in the past 5 my. Basing on the plausible constancy of ^{10}Be flux in the past, ^{10}Be served as an index for "time" in the *in-situ* weathered profiles, and for water added to the "dust" after deposition in the loess plateau, respectively. The former studies unambiguously prove that ^{10}Be / ^{9}Be ratios in authigenic clays in the soil serve as a chronometer for soil weathering at the rock-soil interface and for determining the rate constants for weathering of U, Ca, Na, Mg and K, and climatic changes in the environment.

(D. Lal)

Facilities
at
PRL

Electronics Laboratory

Electronics laboratory is carrying out research activities in the area of hardware implementation and software stimulation of Neural Network and Fuzzy Algorithms. Various algorithms are developed for dedicated high speed hardware, Microcontrollers and DSP devices. Network based algorithms are developed for hand-written character recantation, for walking robots and crime detection problems. The application programs are developed using JAVA for distributed parallel computing in heterogeneous computing environments. A walking robot with ultrasonic vision with fuzzy controller is demonstrated during the Golden Jubilee Exhibition. A large feedback type neural network consisting of sixteen thousand neurons and two hundred fiftysix connections is developed to demonstrate reconstruction of face from the skull image. The finding is reported in an international forensic conference. About 30 under-graduate students from Engineering Colleges undertook their project work in Electronics Laboratory. They worked in the area of Image Processing, Advanced Computer Communication, Data Acquisition System, Fuzzy Controller etc.

PRL LAN is heterogeneous LAN and provides connectivity to more than 175 PC nodes and workstations using DOS, Windows and variants of UNIX OS. Also connectivity to Internet is available through VSAT via ERNET. The network is based on TCP/IP protocol. Network related software development were a mail client with mail read acknowledgment, Interactive Message Handling System for JAVA applets, Partitioning of BP algorithm for Parallel Virtual Machine environment, IP over ISDN for Metropolitan Area Network etc.

Computer Centre

The Computer Centre is equipped with five IBM RS6000-580 workstations. These workstations are interconnected on a FDD1 network forming a powerful workstation cluster. This cluster is further connected to six X-stations and more than 100 PCs and workstations distributed throughout the Laboratory. The system, as mentioned above, is also connected by a VSAT link to the INTERNET. The centre thus provides full connectivity to users from all over the laboratory all the time.

The PRL workstations have appropriate software libraries to provide capability for both numerically intensive work and for visualization of data. The centre is equipped for making colour slides and video tapes of the visualisations.

Apart from this, the centre provides the consultation to the users, teaching to the research students, back-up facility, taking care of Internet and Ethernet and helping users in all respects.

Library

The PRL library subscribes to 178 scientific and technical journals. A large number of Scientific Reports, Data, Maps, etc. are also received. 257 books were added to the Library.

Over 1,30,000 photocopies were made according to requests received from PRL personnel, from other libraries and also from research scholars outside PRL.

Requests were received for obtaining 350 publications from other libraries on Inter-Library-Loan. Most of these publications were loaned by us to other libraries.

During the year, 7280 books and journals were issued. Several queries were received for providing factual information, locating addresses, giving biodata. Extensive literature search was done on the inhouse databases and also on the electronic databases on the Internet.

PRL Library Homepage has been created. On this homepage there is a link to the OPAC (Online Public Access Catalogue). All the journals subscribed by the library have been given listed. The URLs (i.e. Uniform Resource Locators) have been given for all those journals which are in an electronic form. By checking on any such title, one can access the publisher's home page of that title which gives many details, including the contents pages of the latest issues. Fifty titles which are not subscribed, but which are available in electronic format and are of interest to our scientists have also been included. On the homepage, links are provided to several reference tools and databases. The new books, journal issues and latest PRL publications can also be seen on the home page. The URL of the PRL Library home page is : //www.prl.ernet.in/~library.

Workshop

PRL workshop and its extension at Thaltej provide major technical support to the exprimental programmes of various scientific group with the existing facility of machine shop, design section, welding section and painting section.

Some of the important major jobs fabricated during the reporting year are listed below:

1. Fabrication of multiwavelength day glow system which consists of Fabry-Perot mask alignment system with X-Y movement, mirror assembly for elevation scanning, shutter for imaging photon detector.
2. Design and fabrication of sensor for Digital Langmuir probe to be flown on RH560 MK II rockets under ISRO-DLR collaboration. These sensors are hemi-spherical in shape made up of teflon and copper and have been fabricated using critical machining and assembly work .
3. Fabrication of PMT housing using SS304 material with rotating shutter at its opening, optical bench, vacuum couplers with required precision.
4. Fabrication of a plasma gas chamber made of SS304 material capable of sustaining high vacuum, plasma gun, beam splitter and various items for an experiment of dusty plasmas.
5. Design and fabrication of IR photometer which includes precision machining and assembling of various optical components , housing Fabry Perot, flip mirror and rotating mirror etc.
6. Fabrication of sky background brightness measuring photometer.
7. Installation of precision camera on IR telescope and aligning work of finder telescope at Mt. Abu.
8. During the open house on the occasion of the Golden Jubilee Year, the workshop staff contributed in all activities. The working and demonstration models for various groups were fabricated in the workshop. Models of Mt. Abu Gurushikhar Observatory and the Udaipur Solar Observatory and Sun Tracking experiment were fabricated and installed by PRL workshop.

In addition to the above, jobs related to high vacuum, fabrication of structural work, servicing of dome at Mt. Abu, spectrometer work, optical component assembly and miscellaneous jobs were completed. Few technical lectures were also arranged for workshop mechanics.

Engineering Services

The Engineering Services render all technical services pertaining to civil engineering works and related building and laboratory services such as electrical, public health, air-conditioning, inter- communication system, elevators, etc. right from the land acquisition to maintenance of all buildings (residential and non-residential) and its related services for architectural planning, designing, estimating and execution of various civil works and related services, landscaping, horticultural development, interiors and furnishings of buildings and structures of all five campuses- PRL main campus, Colony Campus, Thaltej campus, Mt.Abu campus and Udaipur campus.

Site preparation works were executed for installation of sophisticated research equipments by meeting with all the special requirements.During the year, major Civil Work-Modification & Extension to PRL Guest House, in addition to, preparatory works on the eve of the Golden Jubilee Year celebrations were executed.

Honorary Fellows at PRL

Honorary Fellows at PRL

Professor Hannes Alfvén

Professor J.E. Blamont

Professor S. Chandrasekhar

Acad. V.L. Ginzburg

Professor B. Rossi

Professor J.B. French

Professor A.M.J. Tom Gehrels

Professor D. Lal

Professor P.R. Pisharoty

Professor M.G.K. Menon

Professor S. Dhawan

Professor U. R. Rao

Academic Faculty of PRL

Academic Faculty of PRL

Name	Specialisation	Academic Qualification
Prof G S Agarwal FNA, FASc, FNASc	Quantum Optics, Nonlinear Optics and Laser	Ph D Rochester Univ. (1969)
Prof 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)
Prof A S Joshipura FASc	Particle Physics	Ph D Bombay Univ. (1979)
Prof A K Singhvi	Palaeoclimatology and Geochronology	Ph D IIT, Kharagpur (1975)
Prof S K Bhattacharya FASc	Isotope Geochemistry	Ph D PRL, Gujarat Univ. (1980)
Dr V B Sheorey	Theoretical Atomic Physics and Non linear Dynamics	Ph D Univ. College, London Univ.(1968)

Name	Specialisation	Academic Qualification
Dr S D Rindani	Particle Physics	Ph D IIT, Bombay (1976)
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 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 PRL Gujarat Univ. (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)
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)

Name	Specialisation	Academic Qualification
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 Banerji	Laser Physics	Ph D City Univ.(NY)(1982)
Dr. K S Baliyan	Atomic Physics & Atomic Astrophysics	Ph D Roorkee Univ.(1986)
Dr S. K. Gupta	Geophysics, Hydrology	Ph D IIT, Bombay (1974)
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)
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.(1986)
Dr Rajmal Jain	Solar Physics	Ph D PRL Gujarat Univ. (1983)
Dr. J. R. Bhatt	Astrophysics	Ph D Gujarat Univ. (1992)
Dr. A. Lakshminarayan	Nonlinear Dynamics & Quantum Chaos	Ph D State Univ. NY (1993)
Dr. Ranjit Singh	Laser Physics & Nonlinear Spectroscopy	Ph D IIT, Kanpur (1990)

Deve Gowda to inaugurate PRL function

By A Staff Reporter

AHMEDABAD: Prime Minister H D Deve Gowda will inaugurate a four-day 'Open House' organised by the Physical Research Laboratory as part of its golden jubilee celebrations on Tuesday.

Briefing newspersons, PRL director G S Aggarwal said that the Open House would include an exhibition which will depict various activities of the institute through video shows, slide shows etc.

Besides, the PRL has various meetings, workshops and public lectures on the agenda for the year, some of which have already been held since the celebrations started in November last.

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GANDHINAGAR

FRIDAY, NOVEMBER 22, 1996

PRL scientists urged to uphold tradition

By A Staff Reporter

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આજે વડાપ્રધાન પી.આર.એલ.ના વૈજ્ઞાનિક પ્રદર્શનનું ઉદ્ઘાટન કરશે

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Sky is the limit for research at PRL

■ It remembers members' contribution in its 50th year

EXPRESS NEWS SERVICE
AHMEDABAD, NOV 19

FIVE decades and still young. Life for the scientists at Physical Research Laboratory (PRL), Ahmedabad, the mother institution of research programmes in space and planetary sciences, is always agile. For them, small is not beautiful but in a reversal of their creed big is good, bigger is better and biggest of all is drop-dead gorgeous.

The PRL is celebrating its golden jubilee to commemorate the services of its past members. The celebrations, initiated on November 11, will continue throughout the year.

The amazing growth of this pioneer laboratory, a brain child of Dr Vikram A Sarabhai, was not accompanied by effective campaigning but took years of hard work and consistent performance.

The laboratory founded in November 1947 following an agreement between the Ahmedabad Education Society and Karmakshetra Educational Foundation, had its beginning at M G Science Institute with a few research students and assistants.

He says several pioneers in the field of space research would take active part in the celebrations. "Actually, the objective of our programme is to bring all such persons to a single platform."

Being a premier research institution of the country, the laboratory started research in astronomy and astrophysics and played a seminal role in initiating a space science activity in the country by giving shape to Indian Space Research Organisation (ISRO) and is producing a highly motivated cadre of space scientists and technologists of the highest international calibre. Many alumni have made important contributions in space sciences and cosmic rays and are holding important positions. Some continue to play pioneering role in the evolution and development of India's space programme.

Sarabhai, along with first director, Prof K R Ramanathan, was associated with PRL for almost two decades, with the evolution and development of the space programme. The senior scientists and research scholars believe that it is because of the nurturing, encouragement and inspiration provided by Sarabhai and Ramanathan that the Indian space programme could make rapid progress with a sense of direction and purpose.

"Looking back at PRL's overall achievements over the past five decades, there is every reason to

Then (above) and now : the institute expanding horizons day by day

and doing research on the Himalayas and meteorites found in Kutch region", he explains.

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…શી વિજ્ઞાનના
…ની સિદ્ધિમાં
…ડૉ. વિક્રમ
…ભાને અદ્વિતીય
…વકાશ સંશોધન
…રસ્પર ઉપયોગ
…ગ કરવામાં
…વણી આપ્યો છે
… સ્પેશ સાયન્સ
…તના ફાયદામાં
… કરીને ભારત
…રો હતો.
…બોરેટરીના ડૉ.
…આ સમારંભ
…પ્રારંભમાં
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…ી હતી.
…આર.એલ.ના
…આપેલી ઉત્તમ
…એલ.ની પ્રશંસા
…ન કરી હતી કે,
…ધિત વિષયોના
… અગ્રગણ્ય
…રીકે.
…સભ્ય એવા
… કરતાં સાઠના
વિવિધ પદો પર
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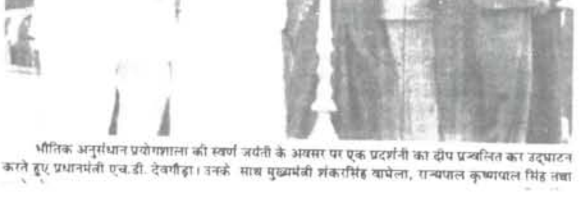
…સ્મરણ પ્રતીક જે
…કોતરેલાં છે તે

[illegible]

Govt committed to support fundamental science: PM

By A Staff Reporter

सरकार विज्ञान के क्षेत्र में अनुसंधान को बढ़ावा देने के लिए कृतसंकल्प -देवगौड़ा



भौतिक अनुसंधान प्रयोगशाला की स्वर्ण जयंती के अवसर पर एक प्रदर्शनी का दीप प्रज्वलित कर उद्घाटन करते हुए प्रधानमंत्री एच.डी. देवगौड़ा। उनके साथ मुख्यमंत्री शंकरसिंह वाघेला, राज्यपाल कृष्णपाल सिंह तथा

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