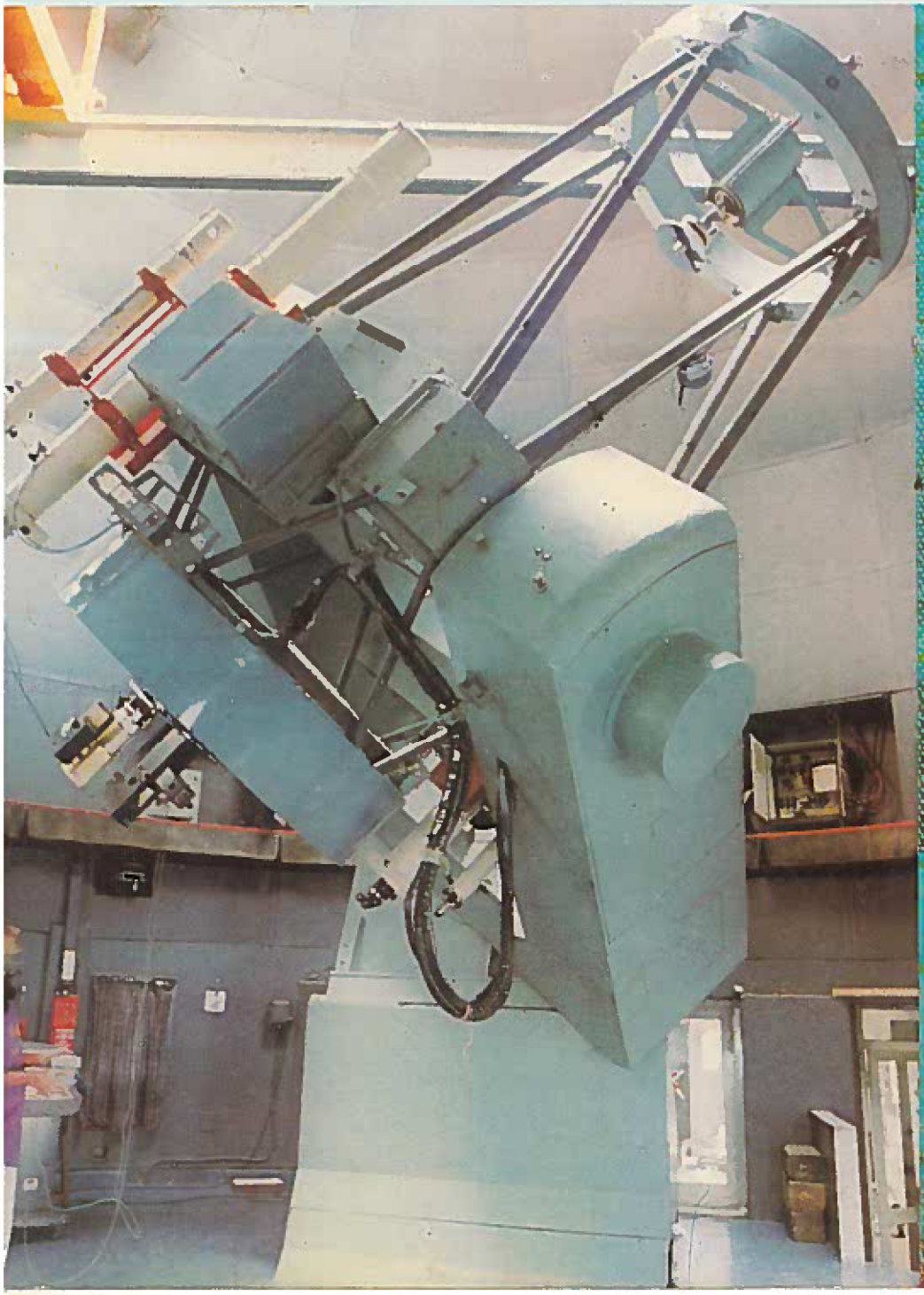
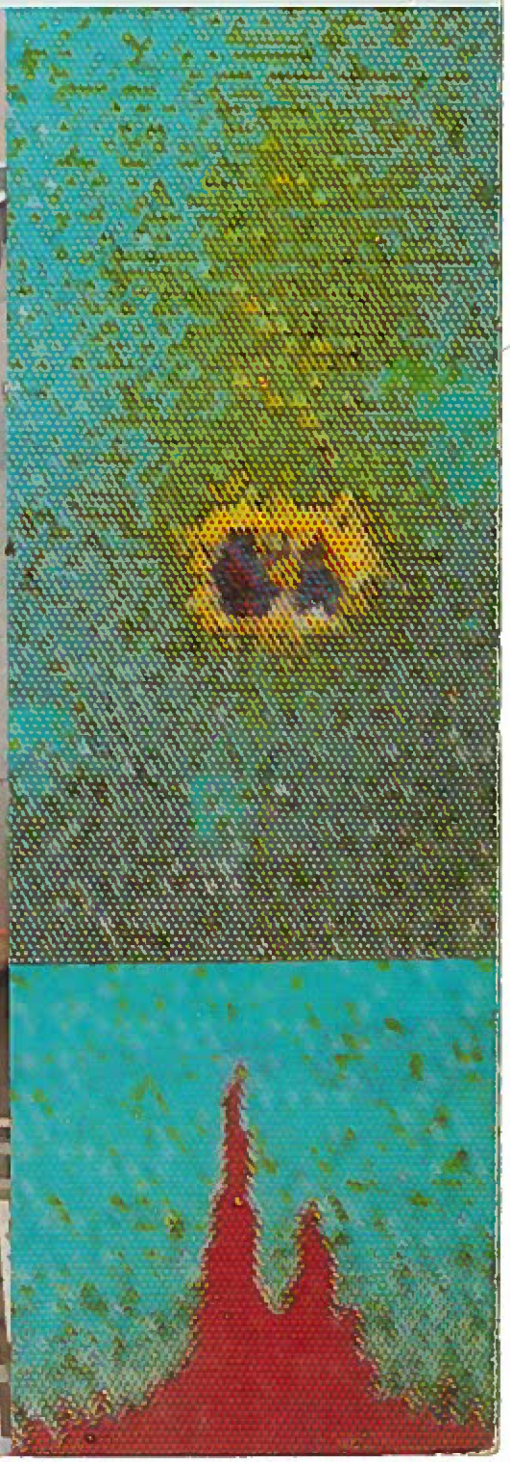
वार्षिक रिपोर्ट
1994-95
ANNUAL REPORT

भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद
PHYSICAL RESEARCH LABORATORY, AHMEDABAD





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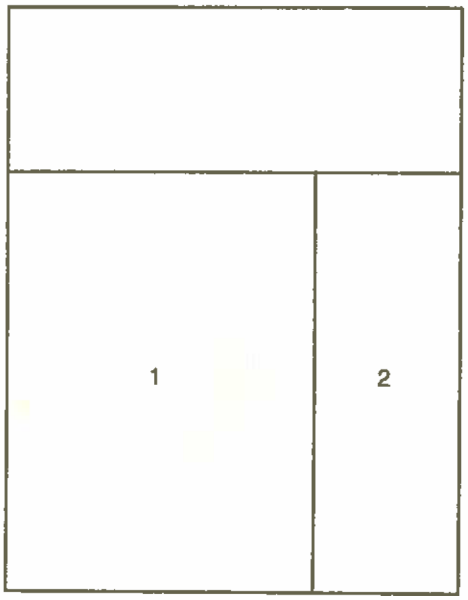

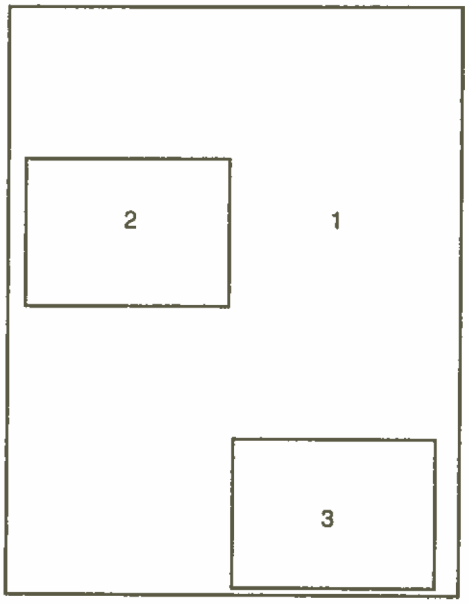

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2. A resolved image of a binary μ Cygni with a seperation of 1.6 arc seconds (top) with intensity plots (bottom).

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3. Lateral Moraine of past glacial advance flanking modern glacier Shalang Gal, Goriganga basin, Pithoragarh.

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Council of Management 1994-95

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Prof. R.K. Varma (Ex-Officio)	Director Physical Research Laboratory

Secretary

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

Introduction

During the year the laboratory continued to make its mark in several areas of physical and earth sciences. The laboratory participated in several national and international programmes. The scientists contributed extensively to the international scientific scene as can be seen from the publications of the laboratory. The laboratory has a strong visitor programme. This year we had the benefit of guidance from several top scientists including the Nobel Laureate Prof. A. Hewish. The laboratory makes special efforts in the development of human resources, through its various training programmes. Our scientists, being aware of their responsibilities to society, organise a number of scientific programmes for the society.

Areas of activities of the laboratory have been reorganised recently. The laboratory now functions in four broad divisions viz. Astronomy and Astrophysics, Planetary Atmospheres and Aeronomy, Earth Sciences and Solar System Studies and Theoretical Physics. The highlights of scientific activities and detailed research programmes of these divisions and important facilities are given in subsequent sections of the report. One of the most important developments in the Astronomy and Astrophysics division during the year 1994-95 was the commissioning of the 1.2m telescope at Gurushikhar.

On August 12, 1994 the Physical Research Laboratory celebrated the 75th birth anniversary of its founder Dr. Vikram A. Sarabhai. In addition to the traditional tree plantation ceremony, there was a photographic exhibition on Dr. Sarabhai which was inaugurated by Smt. Rajshree Sarabhai, daughter-in-law of Dr. Sarabhai. Many close associates of Dr. Sarabhai, Profs. S.P. Pandya, P.C. Vaidya, E.V. Chitnis spoke on "Vikram A. Sarabhai : His Life and Work" in the main celebration programme in the K.R. Ramanathan Hall. The presentation ceremony of Hari Om Ashram Prerit Vikram Sarabhai Research Awards was held as a part of this celebration. Prof. M.G.K. Menon gave away the awards to the distinguished recipients.

A meeting on the Fundamentals of Physics and Astrophysics was held in PRL during March 14-16, 1995. The objective was to learn about the current status of some old and new open questions in Physics. There were invited talks from distinguished scientists on topics of classical and quantum mechanics, statistical mechanics, particle physics and astrophysics with emphasis on conceptual aspects and questions of principle. During this meeting, a special session was arranged to felicitate Prof. R.K. Varma on the occassion of his 60th birthday. The meeting was a great success.

We hope to continue to be in the front-line areas of scientific activity being conducted all over the world. We look forward to a brighter future with more and more exciting contributions to science.

I take this opportunity to thank all my colleagues, administrative, technical and supporting staff for the scientific success of the laboratory.

G S Agarwal

Director

PRL
in a
Nutshell

Scientific Achievements

The Physical Research Laboratory (PRL) is one of the premier research institutions of the country carrying out basic research in several areas of experimental and theoretical physics and earth sciences. Founded by Dr. Vikram A. Sarabhai soon after India's independence, in November 1947, the laboratory had its humble beginning in M.G. Science Institute. The research programmes were oriented and pioneered by the scientific interests of Dr. Vikram A. Sarabhai, PRL's founder and Prof. K.R. Ramanathan, its first Director. The laboratory received recognition of the Atomic Energy Commission and became a grant-in-aid autonomous institution of the Department of Atomic Energy in 1963. With the creation of the Department of Space in 1972, PRL was transferred from the Department of Atomic Energy to the Department of Space. In 1969, PRL played the historic role in initiating the formation of Indian Space Research Organisation (ISRO) with Dr. Vikram Sarabhai as its first chairman. PRL thus served as the cradle of Indian Space Programme in our country.

Having started rather modestly with modest resources, PRL grew very rapidly to become the country's leading space science laboratory. In the early seventies new activities were initiated in the fields of laboratory astrophysics and plasma physics. The Geocosmophysics group which was nucleated at the Tata Institute of Fundamental Research, Bombay, moved to PRL in 1972. In the same decade, Infrared Astronomy and Inter-Planetary Scintillation studies were initiated, which led to the establishment of Infrared Observatory at Gurushikhar and the construction of 3-station IPS radio telescopes at Thaltej (Ahmedabad), Rajkot and Surat. The study of Contemporary Sun is also being carried out at the Udaipur Solar Observatory, Udaipur. The programme on experimental plasma physics which was initiated during the early seventies has now moved out of PRL as Institute of Plasma Research funded by the Department of Science and Technology.

At present the scientific activities of the laboratory can be broadly grouped under four major divisions. They are (i) Astronomy and Astrophysics; (ii) Planetary Atmospheres and Aeronomy; (iii) Earth Sciences and Solar System Studies, and (iv) Theoretical Physics like Plasma Physics, Atomic and Molecular Physics, High Energy Physics, Nuclear Physics, Astrophysics and Climatology. In the following, the highlights of the research activities in each of these fields have been summarised:

Scientific Disciplines

Astronomy and Astrophysics	:	Infrared and Radio Astronomy; Solar Physics.
Planetary Atmospheres and Aeronomy	:	Middle Atmospheric Studies; Upper Atmospheric Studies; Laboratory Astrophysics.
Earth Sciences and Solar System Studies	:	Geochronology; Geochemistry; Nuclear Oceanography and Limnology; Palaeoclimate and Hydrology; Meteorite and Lunar Studies; Cosmic Rays.
Theoretical Physics	:	Astrophysics; Plasma Physics; Meteorology and Climate Studies; Classical and Quantum Physics; Particles and Fields; Nuclear Physics; Atomic and Molecular Physics.

Astronomy and Astrophysics

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

The Astronomy and Astrophysics division of PRL operates from three campuses spread over the states of Gujarat and Rajasthan. Regular monitoring of the sun and the study of energetic phenomena like solar flares are carried out from the Udaipur Solar Observatory (USO) located in the middle of Fatehsagar lake in Udaipur. The Gurushikhar Observatory located at the highest point in the hills around Mt.Abu houses a 1.2 m telescope and is the main centre for optical and infrared astronomical observations. These are being carried out with a variety of highly specialised instruments like infrared high speed photometers, Fabry-Perot spectrometers, optical and infrared polarimeters developed at PRL over a period of a decade and more. The Thaltej campus on the western outskirts of Ahmedabad houses a radio telescope - an antenna array operating at a wavelength of 103 MHz for the study of interplanetary plasma. The Thaltej campus is also the base for the Astronomy and Astrophysics division.

During the year 1994-95, the most important development in the Astronomy and Astrophysics division was the commissioning of the 1.2 m telescope at Gurushikhar. After refiguring work at Sinden Optical Company, Newcastle, U.K., the 1.2 m diameter primary mirror reached Mt.Abu in July 1994. After the monsoon season, a series of optical tests were conducted on the mirror; the primary and its Cassegrain secondary mirror were then installed in their cells and aligned in November 1994. The "first light" star image on α Arietis was acquired on 19 November 1994 which clearly showed the excellent quality of the telescope optics. Astronomical observations immediately commenced with the successful recording of a lunar occultation in the near infrared of the star IRC-10557 (v Aquarii) on December 7, 1994. The telescope has since been in regular use and has given a big boost to observational astronomy at PRL.

The scientists of the Astronomy and Astrophysics division participated actively in two international observational campaigns. Observations on AGN (BL Lac objects) were made to study the rapid variability. Observations in the optical emission lines were carried out on the Be star λ Eridani simultaneous with the X ray observations by the ROSAT satellite, in order to investigate possible association of optical variability with high energy phenomena.

In another international campaign on high angular resolution, lunar occultation observations of the carbon star TX Psc have clearly established the presence of warm dust of a few stellar radii from the stellar photosphere. The different occultation chords across the source indicate a highly asymmetric distribution of dust around TX Psc.

At the Udaipur Solar Observatory chromospheric activity of the superactive flare productive region NOAA 6555 was investigated using high spatial resolution images in H_α along with magnetograms and photo-heliograms. Sub-areas having high magnetic shear and large sunspot motion were found to be most active.

The year 1994 also witnessed a very rare celestial spectacle - the collision of the 21 fragments of a comet (Shoemaker Levy9) with planet Jupiter, during the week July 16-July 23, 1994. As this period was the peak of the monsoon season, limited optical observations were carried out with a small telescope, by the PRL group from Jaisalmar in the Rajasthan desert. Radio observations are however not affected by clouds and were carried out mainly at 4.15 GHz using the dish antenna of the Space Applications Centre, Ahmedabad. These microwave observations particularly during the k fragment impact on July 19, 1994 have exhibited interim oscillations with a varying frequency possibly related to magnetospheric efforts on Jupiter.

Planetary Atmospheres and Aeronomy

The research activities of the Planetary Atmospheres and Aeronomy division are aimed to understand the physical and chemical processes in different regions of the earth's atmosphere and in other planetary and cometary atmospheres. The investigations are based on

balloon and rocket-borne measurements of a number of atmospheric parameters and measurements made by remote probing using a number of optical and radio techniques. These measurements are supplemented by modelling and numerical as well as laboratory simulation studies.

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

In the *upper atmosphere studies*, a case study was made during a moderate magnetic storm event and it was shown that the close coupling of the thermosphere-ionosphere system prevails even during geomagnetically disturbed conditions.

More results have emerged from the multi-technique 'Ionization Hole' experiment conducted earlier during February 1993. Vertical winds of about 20 ms^{-1}, eastward winds exceeding 100 ms^{-1} and strong shears in the meridional winds have been obtained from the vapour cloud release experiment. Mass spectrometer results show molecular ions like NO^+, O_2^+ to be dominant upto apogee, due to the electrodynamical effects in the post-sunset period.

With the availability of the Indian MST radar, experiments were conducted to study the ionization layers observed in the altitude region of 90-150 km by rocket experiments made earlier from Thumba/SHAR during evening and night hours. MST radar was operated on seven nights during 11-18 May, 1994 and the gravity wave parameters are being estimated.

The in-situ electron density profiles obtained from thirty three flights of rocketborne Langmuir probe from Thumba and SHAR have been studied for daytime normal electrojet condition, daytime counter electrojet condition and night time condition respectively to provide input to the International Reference Ionosphere for the low/equatorial latitudes.

Nonlinear numerical simulation studies have shown that the plasma density gradients in the topside largely determine the zonal and vertical extents of the plasma bubbles and their upward movement. These findings can explain the recent reports on the differences in the size and vertical velocity of the plumes, observed by radars at Kwajalein and Jicamarca in the Pacific and Atlantic regions.

The daytime auroral emission measurements using an indigenously developed multiwavelength daytime photometer from Antarctica were continued in 1994-95 with additional wavelengths.

In the *middle atmospheric studies*, an indigenously developed cryogenic air sampler was flown successfully from Hyderabad on April 16, 1994 and vertical profiles of a number of trace gases have been obtained. A comparison with the earlier measurements during 1987 and 1990 shows that the growth rates of some of the gases has decreased, probably due to the phasing out of these gases under the Montreal Protocol. Surface monitoring of the ozone and its precursors over Ahmedabad, an urban site, and Gadanki, a rural site, have been continued. Measurements over Mt. Abu, a free tropospheric site, were carried out during short periods for comparison. A new programme has been initiated to understand the exchange of important trace gases like CO , CH_4 , N_2O, at the air-sea interface and measurements were carried out onboard the ship Sagar Kanya during April-May 1994 and February-March 1995.

Using a time dependent model, the sunrise to sunset ratio of NO_2 has been studied and found to be sensitive to the assumed temperature and ozone profiles. Variability of nitric oxide has been studied based on 78 electron density profiles over Thumba obtained by rocket-borne measurements. The large day to day variability of NO at low latitudes is considered to be due to the variation in the turbopause height.

Using a series of aerosol profiles obtained from the Nd:YAG Lidar operated at PRL since March 1992, an e folding time of 9 months has been observed for the decay of the Mt. Pinatubo volcanic aerosol layer. Using a model study, it has been shown that for a wide range of SO_2 injected into the atmosphere the aerosol microphysical processes, growth and coagulation take place at a faster

rate to give rise to larger particles, hence to a faster removal rate.

A new programme has also been initiated to study the surface aerosol size distribution at Ahmedabad using cascade impactor. An increase in aerosol mass loading from October 1994 to January 1995 is seen with a corresponding change in aerosol size distribution.

In the middle atmospheric electrodynamic studies, stratospheric electrical conductivities measured by balloon-borne experiments during 1984-94 show fluctuations with a periodicity of 20-40 minutes during March-April months and appear to be due to the effect of thunderstorm activity in the pre-monsoon season.

The modelling work on planetary and cometary atmosphere included the exosphere of Mars. Estimated escape flux and density of oxygen ions and electrons through the plasma sheet of Mars agreed with the in-situ measurements of the density of O^+ and show that the polar wind acceleration process is responsible for the escape of ions through the polar region. The other work is related to the chemistry of atomic carbon in Comet Halley. A coupled chemistry transport model has been developed to study the production and loss of atomic carbon due to different sources.

In the *laboratory astrophysics studies*, temperature dependence of the photoabsorption cross sections for carbon tetrachloride in the spectral region of 186-240 nm was studied in the range of 200 to 300 K. The group also successfully designed and fabricated new experiments based on the excimer and dye lasers acquired recently. One of the experiments is to study spectroscopically the laser produced plasma in different targets. The study of such a plume using mild steel as target has confirmed the presence of some emission lines superimposed over a well defined and highly intense continuum radiation extending from 145 to 185 nm. The other experiment is to study the fluorescence spectrum of molecules having small photo absorption and fluorescence cross sections like NO_2 , an important minor constituent in the earth's atmosphere.

Earth Sciences and Solar System Studies

The Earth Sciences and Solar System Studies Division comprises of two scientific areas, the *Oceanography and Climate Studies* and the *Solar System and Geochronology*. The former area focusses on ocean circulation and mixing, air-sea exchange of gases, particle and nutrient dynamics in ocean water column, palaeoclimatic and palaeoenvironmental analysis over a wide range of spatial and temporal scales, and systematics of fresh water systems. The focus of the Solar System and Geochronology area is on studies of catastrophic boundaries in Earth history, evolutionary history of the major Indian land forms and isotopic anomalies in meteorites. Together these two areas integrate a range of activities which addresses to processes operating on the Earth and other solar system objects on various time scales using elemental and isotopic abundances in samples from these bodies.

The thrust of our palaeoclimate programme is to understand the evolution of the Indian monsoon and palaeoenvironmental conditions over different time scales. The loess-palaeosol sections which occur extensively in the Central Europe, China and India provide important continental records. Analyses of the available chronological data on loess-palaeosol profiles reveal that the peak of the loess accumulation occurred at 17 kyrs and not 21.5 kyrs as generally believed. Further, the loess accumulation has been episodic with periods of hiatus and/or substantially reduced accumulation. This study requires closer scrutiny of the reported correlation between the loess-palaeosol record with deep sea oxygen isotopic data as well as the Milankovitch periodicities.

On a much longer time scale, the glaciogenic sediments of the Talchir formation, have provided observational evidence of a mega-monsoonal climate prevailing over the megacontinent, Pangea, during the Permian times, about 270 Myrs ago. Stable isotopic analysis of the carbonate phases of sediments from the Talchir formation, west Bokaro Gondwana basin of Bihar, have yielded extremely light (-16 ‰ to -35 ‰) values of $\delta^{18}O$. The major contributing factor for the highly depleted oxygen isotope composition could be mega-monsoonal circula-

tion resulting in a large 'amount' effect as advocated by climatologists from their global GCM models.

The salt balance of saline Sambhar lake and the evolution of brine has been investigated using chemical and stable isotopic composition of lake waters. The stable isotopic composition ($\delta^{18}O$) of the lake during its recharge is dominated, as expected, by the rainfall. Material balance calculations and modelling of the chemical quality data of the lake brine suggests that redissolution of the halite formed on the lake bed by evaporation of lake water during summer contributes ~ 90% of the salt abundance of the present day lake.

Our hydrology programme has developed methods to conserve, renovate and reuse available water resources in Ahmedabad. The storm water run-off was diverted into the underground aquifers with the twin objectives of solving the flooding problem in low lying areas as well as enhancing the groundwater recharge. For example, the entire storm water run-off from a shopping complex in Maninagar area of Ahmedabad, with about 1500 m^2 plot area, was diverted into a suitably designed percolation well constructed in the basement of the complex. The percolation not only provides a temporary storage of storm water but also causes accelerated percolation of water in the unconfined aquifer. A total of about 1800 m^3 of water was recharged underground during the entire rainy season of 1994.

In addition to the above, efforts to evolve a chronological method to date past seismic events and determine their repeat frequency were continued with samples from the Kumaon Himalaya. The results suggest that 40-50 kyr ago, the Himalayan region was tectonically very active.

The Solar System and Geochronology group has carried out studies related to the (1) evolution of the Indian lithosphere, specially the Deccan volcanic plateau in relation to the Cretaceous-Tertiary boundary and (2) origin of the solar system based on extinct radioactive clocks in primitive grains and evolution of meteorites and their irradiation history. A continued study of these problems over the years has now provided some insight into the physicochemical processes and time scales operating during the formation and evolution of these objects.

High resolution sequence stratigraphy of the Cretaceous-Tertiary Boundary (KTB) events has been obtained based on geochemical, geochronological and palaeomagnetic study of the Anjar trap-intertrap section. Signatures of multiple impact events are found which favour cometary impact scenario. ^{40}Ar-^{39}Ar data obtained for the flows below the KTB at Anjar give ages ranging from 65 to 68 Myrs. Evidence of the oldest crustal components of the Indian shield has been found in zircons from the Singhbum craton dated at ~ 3.6 Gyrs. Study of short-lived extinct radionuclides in the early solar system objects suggests a single low-mass Asymptotic Giant Branch (AGB) star as their plausible source and limits the time required for incorporation of freshly synthesised isotopes and formation of grains in the solar nebula to 0.6 Myrs. Nitrogen and noble gas isotopic signatures in the exotic phases (Q) of primitive meteorites and in martian meteorites provide important clues about their origin.

Theoretical Physics

The research activities of the Theoretical Physics Division fall into two broad categories: Macroscopic Physics and Microscopic Physics. Macroscopic Physics includes the work in Astrophysics, Meteorology and Climate Studies, and Plasma Physics. The work in Atomic and Molecular Physics, Classical and Quantum Mechanics, Nuclear Physics, and Particle Physics belong to the domain of Microscopic Physics. There are, of course, disciplines like Astroparticle Physics, and Classical and Quantum Chaos which form a link between Macroscopic and Microscopic Physics.

In the domain of plasma astrophysics, the equilibrium of rotating thick disc in the presence of external gravity and dipolar magnetic field due to a central object has been investigated by solving a set of MHD equations analytically. It is found that the equilibrium cannot support a toroidal magnetic field of arbitrary strength. Furthermore, it is shown that kinks develop in the magnetic field line structure which can give rise to various plasma instabilities for a strong toroidal component of the magnetic field.

In order to study the mechanisms for the variability of monsoons and tropical circulations on interannual and decadal time scales, a General Circulation Model is necessary. Such a model, with six levels in the vertical and a horizontal resolution of 21 waves, and including various physical processes such as cumulus convection, radiation and planetary boundary-layer fluxes, was developed this year and used for mean planetary summer simulation.

Space Plasmas are often characterized by the presence of a dust component which can either be charged or uncharged. In the case of charged dusty plasmas, new types of magnetoacoustic waves have been predicted. For non-uniform dusty plasmas held in equilibrium in a magnetic field against gravity, there exists a novel flute-like interchange instability. On the other hand, weakly ionized inhomogeneous plasmas are shown to be unstable for high-frequency modes.

In our study of collisions of electrons with excited atoms, we have derived a closed-form expression for the Coulomb-Glauber amplitude for arbitrary and nlm to n'l'm' excitation in the limit of infinite nuclear charge. This helps in the investigation of the nuclear charge dependence of the excitation cross section.

In continuing studies on chaotic quantum systems, the existence of a series of highly localized quantum wave functions in a chaotic coupled quartic oscillator was demonstrated both by visual and by information entropy measures. The relationship of such states with a primary classical periodic orbit revealed subtle interplay between the classical and quantum domain.

A statistical spectral averaging theory is being developed which takes advantages of the algebraic simplicities in nuclear spectroscopic spaces and the action of Central Limit Theorems give the smoothed density of states as a sum of 'interacting' Gaussians, and the transition strength densities as a sum of bivariate Gaussians with partial sums representable as convolution integral. By considering the structure generating a random matrix description of slow-neutron resonance spectra in heavy nuclei and augmenting it by the calculated smoothed state density, it is established that spectral averaging theory is the proper theory for spectroscopy in the "quantum chaotic domain" of complex nuclei.

Direct and indirect experimental evidences suggest that the universe contains dark matter. Heavy weakly-interacting neutral particles, generally thought to make up the so-called "cold" dark matter, was found to have difficulty in explaining certain observations on the microwave background radiation while at the same time accounting for small scale structures in the universe. A scenario was suggested in which a decaying tau neutrino with a mass in the MeV range makes the cold dark matter picture consistent with the observed structures. The proposed scenario also accounts for the solar and atmospheric neutrino deficits seen in a variety of experiments.

CP-violating electric dipole moments of fundamental fermions, if found at an appreciable level, would strongly signal the inadequacy of the "standard model" of fundamental interactions. It has been found that the longitudinally polarized electrons can improve sensitivities by an order of magnitude in the measurement of the tau electric dipole moment at the proposed tau-charm factories, and that of the top-quark dipole moment in future high energy experiments. In the spectroscopy of open flavour mesons, the centre of gravity of masses are explained in the framework of relativistic harmonic confinement model to obtain uniform agreement.

RESEARCH FACILITIES AVAILABLE

Major Equipments

Infrared Telescope at Mt. Abu

Solar Telescope at Udaipur Solar Observatory

Radio Telescope at Thaltej near Ahmedabad

Radio Telescope at Rajkot

Lidar

Gas Chromatograph

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 Spectrophotometer

Atomic Absorption Spectrometer

Ion Chromatographs

Laser Particle Size Analyser

Spinner Magnetometer

Inductively Coupled Plasma Emission Spectrophotometer (ICP-AES)

Mass Spectrometer for Stable Isotopes

Nuclear Track Laboratory and X-ray Diffractometer

Computer

The computing system at PRL consists of a core of 5 RISC - based IBM computers(RS/6000 580) connected by a high speed (100 Mbps) FDDI network. The total space available is 22 GB (Gigabytes). Two of the machines have a RAM of 512 MB. All computers (PCs and work stations)in the campus are connected to the central system through ethernet (ETHERNET) LANs. 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

Library, Workshop, Engineering Services

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	- 38
No. of Post Doctoral Fellows	- 14
No. of Visiting Scientist	- 1

Training Opportunities

PRL provides summer training programme to students doing their Master's degree in Physics to acquaint them with the research programmes and opportunities available at PRL.

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

PRL provides project training in computer science and application to post-graduate students. It also offers training in electronics and computer engineering to engineering and diploma students.

No. of students taken

(i) computer science and application	- 6
(ii) engineering	- 30
(iii) diploma	- 15

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

No. of personnels trained in

(i) computer centre	- 6
(ii) electronics laboratory	- 10
(iii) library	- 1
(iv) maintenance	- 5

(v) workshop - 4

(vi) administrative services - 4

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	- 6
Papers published in journals	
(a) National	- 19
(b) International	- 77
Papers published in proceedings	- 18
Review Articles published	- 6
Books/Journals edited	- 1

Advances in Space Research in India - A Three Decade Profile, INSA Diamond Jubilee Publication, Edited by R.K.Varma, 1994

Papers presented in conferences/seminars etc.	
(a) National	- 79
(b) International	- 49
Invited/Review talks given	- 29

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. Symposium C 2.2 on Variability in the Low Latitude Middle Atmosphere at the 30th COSPAR Scientific Assembly, Hamburg, Germany, July 1994, (Convener- D.K.Chakrabarty).

2. International Symposium and Workshop on Palaeoenvironmental Records of Desert Margins and Palaeomonsoon Variation during the Last 20 ka under UNESCO sponsored International Geological Correlation Programme (IGCP - 349), X'an, China, August 14- 23, 1994 (Convener - A.K. Singhvi).

3. Indian - International Equatorial Electrojet Year (I-IEEY) Data Analysis Workshop (Convener - R.Sridharan)

4. Symposium on Space Research in India - Accomplishments and Prospects (Convener - S.P.Gupta)

5. Fundamentals of Physics and Astrophysics (Convener - J.C.Parikh, S.B.Khadkikar and A.C.Das)

Distinguished Visitors at PRL

PRL invites distinguished sceintists, both from inside and outside the country to interact with our scientists. Some of the distinguished scientists who have visited PRL are Prof.R.K. Onion, Prof.J.E. Blamont, Prof.A. Hewish, Prof.R.Wilson, Prof.P.S.Liss, Prof. E.Derbyshire, Prof.H.Quinzel and Prof.K.I.Oyama.

Dr. N. Sen Roy, Director General, India Meteorology Department (IMD) visited PRL and delivered the **Sixth Ramanathan Memorial Lecture** on Cyclones in the Indian Seas.

Seminars and Colloquia held

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

Seminars held	-	120
Colloquia held	-	35

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

Staff

Scientific	-	70
Technical	-	196
Administrative	-	85
Auxiliary	-	88

Miscellaneous

To popularise science and to create scientific temperament amongst the students, teachers and the general public PRL organised popular lectures in collaboration with the Ahmedabad Chapters of Indian National Science Academy and Indian Physics Association. The National Science Day celebration was dedicated to students and teachers of higher secondary schools.

To popularise Hindi and to implement the use of Hindi at PRL the Hindi Week was celebrated at PRL from 12 -18 September, 1994 for our staff members and their families. The highlights of the celebration included the traditional word quiz, essay, elocution, debate and recitation competition. A one day workshop on Hindi was held on January 5, 1995 for the staff members.

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

Awards and Honours

Prof. S. P. Pandya, our former Director, has been awarded the prestigious Vikram Sarabhai Science Award by the Government of Gujarat for his outstanding contributions to science.

Prof. J. N. Goswami has been awarded the prestigious Shanti Swarup Bhatnagar Prize in Earth, Atmosphere, Ocean and Planetary Science for the year 1994.

Prof. B. H. Subbaraya has been awarded the Space Science and Application Prize of the Astronautical Society of India.

Prof. N. Bhandari has been elected Fellow of the National Academy of Sciences, Allahabad .

Prof. A. Bhatnagar has been elected Fellow of the National Academy of Sciences, Allahabad.

Prof. J. N. Desai has been elected Fellow of the National Academy of Sciences, Allahabad.

Dr. Nagesha N. Rao has been awarded the Associate Membership of the International Centre for Theoretical Physics (ICTP), Trieste, Italy for the period from January 1, 1994 to December 31, 1999.

Dr. Utpal Sarkar has been nominated an Associate Member of the International Centre for Theoretical Physics from January 1, 1995 to December 31, 2000.

D.Pallam Raju's paper on First Results from Ground-based Daytime Optical Investigations of the Development of Equatorial Ionization Anomaly was adjudged the best contributed paper in the category of Upper Atmospheric and Ionospheric Physics at the National Space Science Symposium - 1994, Thiruvananthapuram.

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Theses Submitted During 1994-95

1. **S.Gurubaran**

   Investigation in the low latitude Ionosphere-Thermosphere system (October 1993)

2. **G. Srinivasan**

   Ion microprobe isotopic studies of Ca-Al-rich inclusions from primitive meteorites (June 1994)

3. **S.S. Rathore**

   Geochronological studies of Malani volcanics and associated igneous rocks of southwest Rajasthan, India: Implications to crustal evolution. (July 1994)

4. **Seema P.**

   Kinematic studies in extended astronomical objects (July 1994).

5. **Chakrabarty H.S.**

   Some studies of Electron-atom inelastic collision and high energy capture (August 1994)

6. **D. Majumdar**

   Nuclear level densities and other statistical quantities with interactions in spectral averaging theory: Systematic studies and applications (December, 1994).

PRL Technical Notes

TN-94-74 An inexpensive sidereal drive unit for 1 m class astronomical telescopes by K.S.B. Manian, F.M. Pathan and B.G. Anandarao

TN-95-75 Floppy disk as data storage medium by R.N. Misra (1995)

TN-95-76 Floppy disk based four channel data recorder by R.N. Misra (1995)

Symoposia / Workshops Organised at PRL

International Equatorial Electrojet Year - Data Analysis Workshop (10-12 May 1994)

Symposium on Space Research in India - Accomplishments and Prospects (12 - 13 November 1994)

Fundamentals of Physics and Astrophysics (14-16 March 1995)

Papers Presented in Symposia / Schools in 1994-95

ASTRONOMY ASTROPHYSICS

1. **Desai, J.N.** presented an **invited** paper on Fabri-Perot Spectroscopy and use of Imagining Photon Counting Detectors at the INDO-US Workshop conducted at IUCAA on Array detectors and Image Processing, IUCAA Pune, 28 November-11 December 1994.

2. **Desai, J.N.** presented an **invited** paper on High Resolution Optical & Infrared Astronomical Spectroscopy at the Indo-Japanese Seminar on Astronomy & Astrophysics, Bangalore, January 17-20 1995.

3. **Vats, H.O.** presented an **invited** paper on (i) Solar Radio Astronomy and (ii) Interplanetary Scintillation at the Mini Workshop on Soalr Physics, Meerut University, Meerut, February 15-18 1995.

4. **Vats, H.O.** presented an **invited** paper on Interplanetary Scintillation and Solar Wind Studies at 103 Mhz at IAU Colloquium No.154 "Solar and Interplanetary Transients" held at National Center of Radio Astrophysics, Pune, January 23-27, 1995.

5. **Tripathy, S.C.** presented papers on The Effect of Opacity Modifications on Solar Structure and Oscillations (J. Christensen-Dalsgaard) and Detection of Chromospheric Oscillations in High-l Data (F.Hill) at the GONG 1994: Helio- and Astero-seismology from the Earth & Space, Los Angeles, May 16 -20, 1994.

6. **Vats, H.O.** presented papers on Interplanetary Scintillation Studies at the 103 MHz(M.R.Deshpande), and Radio Brightness Temperature and Solar Wind Acceleration (H.Yadav) at the Eighth International Symposium on Solar Terrestrial Physics, Sendai, Japan, June 5-10, 1994.

7. **Vats, H.O.** presented a paper on Plasma Irregularities in the E Region (H.Chandra, M.R.Deshpande and G.D.Vyas) at the International Workshop on Non Nonlinear Waves and Chaos in Space Plasmas, Kyoto, Japan, June 13-16, 1994.

8. **Muthumariappan, C.** presented a paper on Imaging Fabry Perot Spectometer at the Young Astronomer's Meet, IUCAA, Pune, August 1-5, 1994.

9. **Chandrasekhar, T.** presented a paper on Near Infrared Coronal Line Emissionin Nova Herculis 1991(N.M.Ashok and Sam Ragland) at the International Astronomical Union, XXIInd General Assembly : IAU Symposium 165 on Compact Stars in Binaries, the Hague, Netherlands, August 1994.

10. **Chandrasekhar, T.** presented a paper on Near Infrared High Angular Resolution Observations of Stars and Circumstellar Regions by the Technique of Lunar Occultations(N.M.Ashok and Sam Ragland) at the International Astronomical Union XXIInd General Assembly: IAU Symposium, 166, Astronomical and Astrophysical Objectives of Sub-Milliarcsecond Astrometry, The Hague, Netherlands, August 1994.

11. **Ashok, N.M.** presented a paper on Infrared Photometric Techniques at the II Workshop on Experimental Techniques in Space Sciences and Astronomy, Gujarat University, Ahmedabad. September 13-17, 1994.

12. **Joshi, U.C.** presented a paper on Standardization and Calibration of CCD images at the II Workshop on Experimental Techniques in Space Sciences and Astronomy, Gujarat University, Ahmedabad, September 13-17, 1994.

13. **Ambastha, A.** presented a paper on Solar Imagery with 2D Detectors at the II Workshop on Experimental Techniques in Space Sciences and Astronomy, Gujarat University, Ahmedabad, September 13-17, 1994.

14. **Chakraborty, A.** presented a paper on Velocity Field Around Herschel 36 in NGC 6523 (B.G.Anandarao, and D.P.K.Banerjee) at the XVI Meeting of Astronomical Society of India,IUCAA, Pune, October 25-28, 1994.

15. **Watson, P.V.** presented a paper on V, R and I Observations of the Contact Binary System Ak Her (N.M.Ashok and T.Chandrasekhar) at the XVI Meeting of Astronomical Society of India,IUCAA, Pune, October 25-28, 1994.

16. **Ambastha, A.** presented a paper on A Large Flare in an Area of Weak Magnetic Field and Low Shear - A Counter-Example (Mona J. Hagyard, and E.A. West) at the XVI Meeting of Astronomical Society of India,IUCAA, Pune, October 25-28, 1994.

17. **Ambastha, A.** presented a paper on Chromospheric, Photospheric, Magnetic Field Evolution and Flare activity of the Super Active region NOAA 6555.(Debi Prasad C, Nandita Srivastava, Sushant C. Tripathy) at the XVI Meeting of Astronomical Society of India,IUCAA, Pune, October 25-28, 1994.

18. **Deshpande, M.R.** presented a paper on "Microwave Emission and Bursts during Comet Shoemaker-Levy 9 Encounter (O.P.N. Calla, Hari Om Vats, P.Janardhan, N.M.Vadher, V.Sukumaran and B.M.Darji) at the XVI Meeting of Astronomical Society of India,IUCAA, Pune, October 25-28, 1994.

19. **Vats, H.O.** presented a paper on Radio Flare of Π Leo (M.R.Deshpande) at the XVI Meeting of Astronomical Society of India,IUCAA, Pune, October 25-28, 1994.

20. **Vats, H.O.** presented a paper on Solar Plasma and Acceleration (M.Mehta) at the XVI Meeting of Astronomical Society of India,IUCAA, Pune, October 25-28, 1994.

21. **Bhatnagar, A.** presented a paper on Solar Mass Ejections and Coronal Holes at the IAU Colloquium No. 154 on Solar and Interplanetary Transients held at National Center of Radio Astrophysics, Pune, January 23-27, 1995.

22. **Bhatnagar, A.** presented a paper on Transient Phenomena in the Energetic, behind the Limb Solar Flare of September 29, 1989 (R.M. Jain, J.T. Burkepile, I.M. Chertok et al.) at the IAU Colloquium No. 154 on Solar and Interplanetary Transients held at National Center of Radio Astrophysics, Pune, January 23-27, 1995.

23. **Deshpande, M.R.** presented a paper on Solar Radio Burst (Type III) (Hari Om Vats and K.N.Iyer) at the IAU Colloquium No.154 on Solar and Interplanetary Transients held at National Center of Radio Astrophysics, Pune, January 23-27, 1995.

24. **Ambastha, A.** presented a paper on The Sun: Our Daytime Star at the Miniworkshop on Solar Physics, Meerut University, Meerut, February 15-18, 1995.

25. **Ambastha, A.** presented a paper on Some Aspects of Solar Activity at the Miniworkshop on Solar Physics, Meerut University, Meerut, February 15-18, 1995.

26. **Anandarao, B.G.** presented a paper on A near-IR imaging Fabry-Perot Spectrometer for Emission Line Studies on Extended Astronomical Objects(J.N.Desai, N.M.Ashok, D.P.K.Banerjee and T.Chandrasekhar) at the National Symposium on Optics and Opto-Electronic Instrumentation XIV Optical Society of India Meeting, CSIO, Chandigarh, 29-31 March, 1995.

27. **Desai, J.N.** presented a paper on Interferometric Instruments for Solar Eclipse Observations: 1995 Total Eclipse (B.G.Anandarao, T.Chandrasekhar, N.M.Ashok and M.S.Nandakumar) at the National Symposium on Optics and Opto-Electronic Instrumentation XIV Optical Society of India Meeting, CSIO, Chandigarh, 29-31 March, 1995.

PLANETARY ATMOSPHERES AND AERONOMY

28. **Gupta, S.P.** presented an **invited** paper on E and F Region Rocket and Ionosonde Measurements Comparison with IRI at the Workshop on Low and Equatorial Latitude in the International Reference Ionosphere, NPL, New Delhi, January 9-13, 1995.

29. **Chakrabarty, D. K.** presented an **invited** paper on Chemistry of Ozone Depletion at the International Asian Regional Workshop on Ozone Depletion and Management of ODS Phaseout in SMEs, New Delhi, February 7-10, 1995.

30. **Jayaraman, A.** presented an **invited** paper on Investigation of Optical Properties of Aerosol - An Overview at the Workshop on Optics of Aerosols, IITM, Pune, March 23-24, 1995.

31. **Chandra, H.** presented a paper on Daytime F-region Scintillation Observations at Low Latitude (Vyas, G.D., Pathan, B.M. and Rao, D.R.K.) at the International Beacon Satellite Symposium, University of Wales, Aberystwyth, UK, July 11-15, 1994.

32. **Chandra, H.** presented a paper on Coordinated In-situ Scintillations and Ionosonde Observations of Equatorial Spread-F (Vyas, G.D., Sinha, H.S.S., Prakash, S. and Misra, R.N.) at the International Beacon Satellite Symposium, University of Wales, Aberystwyth, UK, July 11-15, 1994.

33. **Chandra, H.** presented a paper on Radio Star and Satellite Scintillations Associated with E-region in the Anomaly Crest Region (H.O. Vats, Deshpande, M.R. and Vyas, G.D.) at the International Beacon Satellite Symposium, University of Wales, Aberystwyth, UK, July 11-15, 1994.

34. **Chandra, H.** presented a paper on VHF Scintillations over Nagpur/Ahmedabad in the Anomaly Crest Region (Navneeth, G.N., Koparkar, P.V., Dhopte, N.P., Vali, A.S.and Vyas,G.D.) at the International Beacon Satellite Symposium, University of Wales, Aberystwyth, UK, July 11-15, 1994.

35. **Chakrabarty, D. K.** presented a paper on the Variability of Mesospheric Nitric Oxide at Low Latitude at the 30th COSPAR Scientific Assembly, Hamburg, Germany, July 11-21, 1994.

36. **Haider, S. A.** presented a paper on O⁺ Escape through the Plasmasheet of Mars and its Causative Mechanism at the 30th COSPAR Scientific Assembly, Hamburg, Germany, July 11-21, 1994.

37. **Haider, S. A.** presented a paper on Study of the Chemistry of the Ions corresponding to 32-50 amu in the Inner Comma of Comet Halley at the 30th COSPAR Scientific Assembly, Hamburg, Germany, July 11-21, 1994.

38. **Gupta, S.P.** presented a paper on Thin Layers of Ionization Observed by Rocket-borne Probes in Equatorial E-region at the 30th COSPAR Scientific Assembly, Hamburg, Germany, July 11-21, 1994.

39. **Gupta, S.P.** presented a paper on In-situ Measurements of Electron Temperature and Density Profiles in the Equatorial Ionosphere at the 30th COSPAR Scientific Assembly, Hamburg, Germany, July 11-21, 1994.

40. **Gupta, S. P.** presented a paper on Balloon-borne Measurements of Conductivity and Electric Field over Indian Zone during Last Ten Years" at 30th COSPAR Scientific Assembly, Hamburg, Germany, July 11-21, 1994.

41. **Sekar, R.** presented a paper on A Case Study on the Evolution of Equatorial Spread-F by a Nonlinear Numerical Model using Results from Coordinated Measurements (R. Raghavarao and R. Suhasini) at the 30th COSPAR Scientific Assembly, Hamburg, Germany, July 11-21, 1994.

42. **Sekar, R.** presented a paper on Threshold Amplitude of Seeding Perturbation for the Evolution of Plasma Bubbles in the Equatorial F region: A Study by a Nonlinear Model (R. Suhasini and R. Raghavarao) at the 30th COSPAR Scientific Assembly, Hamburg, Germany, July 11-21, 1994.

43. **Sridharan, R.** presented a paper on Prediction of Post-sunset Equatorial Spread-F from the OI 630.0 nm Dayglow Measurements (D. Pallam Raju, R. Raghavarao and P.V.S. Ramarao) at the 30th COSPAR Scientific Assembly, Hamburg, Germany, July 11-21, 1994.

44. **Sridharan, R.** presented a paper on Optical Investigation of Daytime Aurora(D. Pallam Raju, R. Narayanan, B. H. Subbaraya and N. K. Modi) at the 30th COSPAR Scientific Assembly, Hamburg, Germany, July 11-21, 1994.

45. **Kumar, V.** presented a paper on Measurement of Photoabsorption Cross sections for Carbon Tetrachloride at 185-240 nm (Prahlad, V.) at the Fourteenth International Conference on Atomic Physics, Boulder, Colorado, USA, July 31-August 5, 1994.

46. **Lal, S.** presented a paper on Monitoring of Surface Ozone and its Precursors at Ahmedabad (Manish Naja, Patra, P.K., Subbaraya, B.H. and Venkatramani, S.) at the Joint 8th CACGP Symposium and 2nd IGAC Conference, Fuji-Yoshids, Japan, September 5-9, 1994.

47. **Lal, S.** presented a paper on Seasonal and Long Term Variations in Surface Ozone at Ahmedabad (Subbaraya, B.H. and Manish Naja) at the Joint 8th CACGP Symposium and 2nd IGAC conference, Fuji-Yoshids, Japan, September 5-9, 1994.

48. **Ramachandran, S.** presented a paper on A Novel Sun Photometer using Light Emitting Diodes (Acharya, Y. B., Jayaraman, A.and Subbaraya B. H.) at the National Space Science Symposium, Thiruvananthapuram, December 20-24, 1994

49. **Haider, S. A.** presented a paper on Ions escape Through the Plasmasheet of Mars at the National Space Science Symposium, Thiruvananthapuram, December 20-24, 1994

50. **Lal, M.** presented a paper on Variation of O_3, NO_2 and NO_3 after Pinatubo Eruption (S. Pashin, D. K. Chakrabarty and K. V. Pandya) at the National Space Science Symposium. Thiruvananthapuram, December 20-24, 1994

51. **Naja, M.** presented a paper on Surface ozone and Precursors at Urban and Remote Sites (Shyam Lal, Patra P. K., Subbaraya, B. H. and Venkataramani, S) at the National Space Science Symposium, Thiruvananthapuram, December 20-24, 1994.

52. **Pallam Raju, D.** presented a paper on First Results from Ground-based Daytime Optical Investigations of the Development of Equatorial Ionization Anomaly (R. Sridharan., S. Gurubaran and R. Raghavarao) at the National Space Science Symposium, Thiruvananthapuram, December 20-24, 1994.

53. **Patra, P.K.** presented a paper on Vertical Distribution of Trace Gases over Hyderabad (Lal, S. and Subbaraya, B.H.) at the National Space Science Symposium, Thiruvananthapuram, December 20-24, 1994.

54. **Ramachandran, S.** presented a paper on Balloon-borne studies of the Pinatubo Volcanic Aerosol Layer over Hyderabad (Jayaraman, A., Acharya, Y.B. and Subbaraya, B.H.) at the National Space Science Symposium, Thiruvananthapuram, December 20-24, 1994.

55. **Pallam Raju, D.** presented a paper on Optical Investigation of Daytime Auroral Emissions from Antarctica (R. Sridharan, R. Narayanan, B. H. Subbaraya and R. Raghavarao) at the National Space Science Symposium, Thiruvananthapuram, December 20-24, 1994

56. **Pallam Raju, D.** presented a paper on Ionization Hole Experiment - Coordinated Rocket and Ground based Measurements at the Onset of Equatorial Spread-F (R. Sridharan, H. S. S. Sinha, R. Sekar, R. Narayanan, S. R. Das, H. Chandra, N. K. Modi, R. N. Misra, B.H. Subbaraya, R. Raghavarao, P. B. Rao, V. V. Somayajulu and V.V. Babu) at the National Space Science Symposium, Thiruvananthapuram, December 20-24, 1994

57 **Pallam Raju, D.** presented a paper on A New Multiwavelength Daytime Photometer (R. Sridharan, N. K. Modi and R. Narayanan) at the National Space Science Symposium, Thiruvananthapuram, December 20-24, 1994

58. **Pant, T. K.** presented a paper on The Low Latitude Thermosphere-Ionosphere System during Moderate Geomagnetic Storm (S. Gurubaran and R. Sridharan) at the National Space Science Symposium, Thiruvananthapuram, December 20-24, 1994

59. **Sinha, H.S.S.** presented a paper on Electron Densities in the Equatorial Lower Ionosphere over Thumba and SHAR (Prakash, S.) at the Workshop on Low and Equatorial Latitude in the International Reference Ionosphere, NPL, New Delhi, January 9-13, 1995.

60. **Chandra, H.** , presented a paper on Bhartiya Bhusthir Upgrah Mein Radio Beacon ki Awashyakata (Hari Om Vats) at Inter Centre Workshop in Hindi, Valiamala, Trivandrum, January 18, 1995.

61. **Chandra, H.** presented a paper on Temperature Structure and Dynamics Studies by Rayleigh Lidars (Jayaraman, A.) at the National Symposium on Advanced Technologies in Meteorology - TROPMET-95, NRSA, Hyderabad, February 8-11, 1995.

62. **Naja, M.** presented a paper on Role of CH_4, CO and NO_x in the Distribution of Surface Ozone (Lal, S., Patra, P.K., Subbaraya, B.H. and Venkatramani, S.) at the National Symposium on Advanced technologies in Meteorology - TROPMET-95, NRSA, Hyderabad, February 8-11, 1995.

EARTH SCIENCES AND SOLAR SYSTEM STUDIES

OCEANOGRAPHY AND CLIMATE STUDIES

63. **Singhvi, A.K.** presented an **invited** paper on Luminescence Chronology, Aeolian Accumulation and Climate Epochs : A Synthesis (M.S. Rao, C.S.R. Murty and R.K. Pant) at Pole - Equator - Pole - II Transect Workshop of IGBP/PAGES at Beijging, April 7-12-1994.

64. **Singhvi, A.K.** presented an **invited** paper on Luminescence Dating and Appraisal at the International Symposium and Workshop on Paleoenvironmental Records of Desert Margins and Paleomonsoon Variation during the Last 20ka, X'an, China, August 14-23, 1994.

65. **Singhvi, A.K.** presented an **invited** paper on Optically Stimulated Luminescence; and Appraisal at the Fifteenth Annual Conference of the Association of Medical Physicists in India, Ahmedabad, November 8-10, 1994.

66. **Singhvi, A.K.** presented an **invited** paper on Archaeological Chronology and Thermoluminescence Dating at the World Archaelogical Congress, Delhi, December 3-12, 1994.

67. **Singhvi, A.K.** presented an **invited** paper on Quaternary Landspace Evolution of a Part of Bengal basin: A Pedological Approach (L.P. Smith and B. Prakash) at the Tenth Convention of Indian Association of Sedimentologists, Dharwad, November 1994.

68. **Ramesh, R.** presented an **invited** paper on High and Coarse Resolution Palaeoclimatic Records from India at the Pole-Equator-Pole- II Transect Workshop of IGBP/PAGES at Beijging, April 7-12 1994.

69. **Bhattacharya, S.K.** , presented a paper on Isotopic Records of Gondwana Glaciation in Talchir Sediments (Chakraborty, A.) at the ICOG-8 (International Conference on Geochronology Cosmochronology and Isotope Geology), Berkeley, California, USA, June 5-11, 1994.

70. **Somayajulu, B.L.K.** presented a paper on Understanding Lateritisation Processes through Compositional, U-Th Decay Series Isotopes and Sr^{87}/Sr^{86} studies (Gopalan, K., Pantulu, G.V., Radhakrishna, B.P., Rengarajan, R. and Sarin, M.M.) at the ICOG-8 (International Conference on Geochronology Cosmochronology and Isotope Geology), Berkeley, California, USA, June 5-11, 1994.

71. **Somayajulu, B.L.K.** presented a paper on Palaeoceanography with ^{10}Be at the ICOG-8 (International Conference on Geochronology Cosmochronology and Isotope Geology), Berkeley, California, USA, June 5-11, 1994.

72. **Kusumgar, S.** presented a paper on A Comparative Study of Monsoonal and Non-monsoonal Himalayan Lakes, India (Agrawal, D.P. and Deshpande,R.D) at the 15th International Radiocarbon Conference, Glasgow, Sctoland, August 15-19, 1994.

73. **Sharma, P.** presented a paper on Water Problems of Gujarat State : Some Innovative Solutions at the Workshop organized by Institution of Engineers (India) , Gujarat State Centre, Ahmedabad, September 18, 1994.

74. **Nijampurkar, V.N.** presented a paper on Recent Studies on Half-life of ^{32}Si based on Varved Lake Sediments at the Isotope Colloquium held at Freiberg, Germany, September 28-30, 1994.

75. **Gupta, S.K.** presented a paper on Urban Environmental Maps, Utility for Storm Water and Groundwater Recharge in Ahmedabad at the Workshop on Urban Environmental Maps, Gandhi Labour Institute, Ahmedabad, November 21-22, 1994.

76. **Somayajulu, B.L.K.** presented a paper on Global Sediment Input to the Coastal Oceans : Present and Past at the IGBP Center-Core Project Workshop on Modelling the Delivery of Terrestrial Materials to Fresh Water and Coastal Ecosystems, University of New Hampshire, Durham, NH, USA, December 5-7, 1994.

77. **Ray, J.S.** presented a paper on Stable Isotope Studies on Ambadongar Carbonatites (Ramesh, R., Trivedi, J.R. and Patel, P.P.) at the Symposium on Mantle Dynamics and its Relation to Earthquake and Volcanism, Calcutta, December 12-14, 1994.

78. **Ray, J.S.**, presented a paper on Isotopic Evolution of a Source from which Many Phases Separate out Simultaneously (Ramesh, R.) at the Symposium on Mantle Dynamics and its Relation to Earthquake and Volcanism, Calcutta, December 12-14, 1994.

79. **Gupta, S.K.** presented a paper on Solving drinking Water Problem in Rural Gujarat: Natural Constraints and Possible Solutions (Sharma, P.) at the Workshop organized by Gujarat Institute of Development Research, Gota, Ahmedabad, January 25, 1995.

80. **Ramesh, R.** presented a paper on Isotope Dendroclimatological Studies in India at the International Workshop on Asian and Pacific Dendrochronology, Tokyo, Japan, March 4-9, 1995.

81. **Ramesh, R.** presented a paper on Stable Carbon and

Hydrogen in the Irish Oak Chronology (Baillie, M.G.L., Pilcher, J.R. and Pollard, M.) at the International Workshop on Asian and Pacific Dendrochronology, Tokyo, Japan, March 4-9, 1995.

82. **Gupta, S.K.** presented a paper on An Innovative Approach for Water Supply and Sewerage (Shah Mayur, P. and Sharma, P.) at the Annual Day of Indian Water Works Association, Ahmedabad Chapter, March 25, 1995.

83. **Sharma, P.** presented a paper on Innovative Approaches in Managing Water Supply Related Problems of Urban Areas like Ahmedabad at the Interdisciplinary Seminar on Urban Environment, School of Social Sciences, Gujarat University, Ahmedabad, March 28, 1995.

SOLAR SYSTEM AND GEOCHRONOLOGY

84. **Goswami, J.N.** presented an **invited** paper on Nuclear Track and Cosmogenic Records in Meteorites at the IX th National Symposium on Solid State Nuclear Track Detector, March 8-10, 1995, BARC, Bombay.

85. Tarieco, C. with **Bhandari, N.** presented a paper on The 11 year Solar Cycle Variation of Cosmogenic Isotope Production Rates in Chondrites (G.Bonino and G.Cini Castagnoli) at the 57th Meteoritical Society Meeting, Prague, Czech Republic, 25-29, July 1994.

86. **Goswami, J.N.** presented a paper on Ion Microprobe Studies of a Carbonaceous (CM) Xenolith in the Eravan Howardite (S. Sahijpal, M.A. Nazarov) at the 57th Meteoritical Society Meeting, Prague, Czech Republic, 25-29, July 1994.

87. **Goswami, J.N.** presented a paper on Nuclear Track Studies of the SNC Meteorite ALH 84001 (N. Sinha) at the 57th Meteoritical Society Meeting, Prague, Czech Republic, 25-29, July 1994.

88. **Goswami, J.N.** presented a paper on Excess ^{41}K in CV_3 Chondrite (G. Srinivasan, A.A. Ulyanov and I.D. Hutcheon) at the 57th Meteoritical Society Meeting, Prague, Czech Republic, 25-29, July 1994.

89. **Bhandari, N.** presented a paper on Cosmic Ray Gradients in the Heliosphere Based on Isotope Production Rates in Meteorites (Ballabh, G.M.) at the XX National Space Science Symposium, Thiruvananthapuram, 20-24, December 1994.

90. **Murty, S.V.S.** presented a paper on Cosmic Ray Produced Neon and Argon in Efremovka Meteorite at the XX National Space Science Symposium, Thiruvananthapuram, 20-24, December 1994.

91. **Wiedenbeck, M.** presented a paper on Zircon Geochronology using a Small Ion Microprobe (J.N. Goswami) at the 8th International Conference on Geochronology, Cosmochronology and Isotope Geology, Berkeley, USA, June 5-11, 1994.

92. **Wiedenbeck, M.** presented a paper on Single Zircon Ages from the Precambrian Basement of the Southern Aravalli Mountains (Rajasthan, India) (J.N. Goswami and A.B. Roy) at the 8th International Conference on Geochronology, Cosmochronology and Isotope Geology, Berkeley, USA, June 5-11, 1994.

93. **Venkatesan, T.R.** presented a paper on , Ar-Ar Chronology of the Ladakh Collision Zone, North-West India (K. Pande, K.K. Sharma and N.S. Chawla) at the 8th International Conference on Geochronology, Cosmochronology and Isotope Geology, Berkeley, USA, June 5-11, 1994.

94. **Goswami, J.N.** presented a paper on ^{41}Ca in the Early Solar System at the Third International Symposium on Nuclei in the Cosmos, Gran Sasso, Italy, July 8-13, 1994.

THEORETICAL PHYSICS

MACROSCOPIC PHYSICS

Meteorology and Climate Studies

95. **Thomas, B.** presented a paper on Climate Modelling for the I-DGBP Related Studies (Kasture, S.V. and Satyan, V.) at National Space Science Symposium, Trivandrum, December 20-24,1994.

96. **Kasture, S.V.** presented a paper on Modelling of the Effects of Orography and Convection in the Monsoon Basic Flow (Thomas, B. and Satyan, V.) at the TROPMET-95 National Symposium on Advanced Technologies in Meteorology, NRSA,Hyderabad, Feb 8-11,1995.

Plasma Physics

97. **Das, A.C.**, presented an **invited** paper on Ionosphere-Magnetosphere Interaction at the Brainstorming Session on Coupled Phenomena in Geo-environment, NPL, New Delhi, September 21-22, 1994.

98. **Das, A.C.** presented an **invited** paper on Magnetosphere of Compact Object at the 9th National Symposium on Plasma Science and Technology - Plasma-94, Guwahati, November 14-17, 1994.

99. **Rao, N.N.** presented an **invited** paper On KdV, Boussinesq and Nonlinear Schrödinger Equations at the International Workshop on From ODEs to Deterministic Chaos, University of Durban-Westville, Durban (South Africa), May 12-15, 1994.

100. **Rao, N.N.**, presented an **invited** paper on Coupled Scalar Field Equations for Nonlinear Wave Modulations at a meeting on Fundamentals of Physics and Astrophysics, PRL, March 14-16, 1995.

101. **Varma, R.K.** presented an **invited** paper on A Generalized Schrödinger Formalism as a Hilbert Space Representation of a Generalized Liouville Equation at a meeting on Fundamentals of Physics and Astrophysics, PRL, March 14-16, 1995.

102 **Rao, N.N.** presented a paper on O-Mode Conversion into Upper-Hybrid and Bernstein Waves in Ionospheric Modification Experiments at the VIII National Space Science Symposium, Trivandrum, December 20-24, 1994.

103. **Varma, R.K.** presented a paper on Discrete Allowed and Forbidden States in the Classical Mechanical Domain in the Charged Particle Motion in a Magnetic Field at the International Conference on Plasma Physics, Foz du Iguacu, Brazil, October 28-November 3, 1994.

MICROSCOPIC PHYSICS

Atomic and Molecular Physics

104. **Baliyan, K.S.** presented an **invited** paper on The Effects of the Resonances on the Electron/Photon Interactions with Atoms and Ions at the Xth National Conference on Atomic and Molecular Physics, Meerut, March 7-11, 1995.

105. **Dewangan, D.P.** presented an **invited** paper on Charge Transfer Processes in Energetic Ion-atom Collisions at the National Workshop on Atomic Physics with High Energy Heavy Ions (NWAPHEHI'94), Banaras Hindu University, Varanasi, April 18-20, 1994

106. **Baliyan, K.S.** presented a paper on Intercombination Line Strengths for Astrophysical Interest in O_I at the Xth National Conference on Atomic and Molecular Physics, Meerut, March 7-11, 1995.

107. **Chakrabarti, S.** presented a paper on Positron-hydrogen Scattering in a Multiple Scattering Model (Dewangan, D.P.) at the Xth National Conference on Atomic and Molecular Physics, Meerut, March 7-11, 1995.

Classical and Quantum Mechanics

108. **Varma, R.K.** presented a paper on Quantum-like Manifestation in Charged Particle Motion in a Magnetic Field at the International Workshop on Quantum-like Model and Coherent States, Erice, June 13-20, 1995.

Nuclear Physics

109. **Kota, V.K.B** presented an **invited** paper and presented a paper on sdg Interacting Boson Model: Some Analytical and Numerical Aspects (Devi, Y.D.) at Perspectives for the Interacting Boson Model, Padova, Italy, June 13-17, 1994.

110. **Kota, V.K.B.**, presented an **invited** paper on Nuclear Spectroscopy in Large Shell Model Spaces : Recent Advances at the Nuclear Structure Physics, Roorkee, February 7-10, 1995.

111. **Khadkikar, S.B.** presented a paper on Strong Interaction Theory at the IPA Seminar on Nuclear Physics : Challenges and Opportunities, BARC, Bombay, June 4-8, 1994.

112. **Khadkikar, S.B.** presented a paper on Equation of State of Quark Matter and Hybrid Stars (Mishra, A. and Mishra, H.) at the DAE Symposium on Nuclear Physics, Utkal University, Bhubaneswar, December 26-30, 1994.

113. **Majumdar, D.** presented a paper on Nuclear Level Densities in Spectral Averaging Theory in Large Shell

Model Spaces: First Systematic Study of fp-shell Nuclei (Kota, V.K.B.) at the DAE Symposium on Nuclear Physics, Utkal University, Bhubaneswar, December 26-30, 1994.

114. **Majumdar, D.** presented a paper on Non Interacting Particle Strength Densities in Large Shell Model Spaces for One-Body Transition Operators (Kota, V.K.B.) at the DAE Symposium on Nuclear Physics, Utkal University, Bhubaneswar, December 26-30, 1994.

Particle Physics

115. **Ganguly, A.K.** presented an **invited** paper on Effective Lagrangian in the Presence of an External Chromoelectric Field at Zero and Finite Temperature at a Discussion Meeting on QCD and Effective Field Theories, Centre for Theoretical Studies and Jawaharlal Nehru Centre for Theoretical Studies, Bangalore, August, 1994.

116. **Mohanty, S.** presented an **invited** paper on Particle Physics Bounds from Astrophysics at the XI DAE HEP Symposium, Viswa Bharati University, December 28, 1994 - January 2, 1995.

117. **Sarkar, U.** presented an **invited** paper on Baryogenesis from a Lepton Asymmetric Universe at the COSY Colloquium at the University of Bochum, December 20-21, 1994, Bochum, Germany.

118. **Rindani, S.D.** presented an **invited** paper on CP Symmetry and its Violation in Fundamental Interactions at a meeting on Fundamentals of Physics and Astrophysics, PRL, March 14-16, 1995.

119. **Ganguly, A.K.** presented a paper on Thermal Effective Lagrangian Screening in the Presence of an External Field at the XI DAE HEP Symposium, Viswa Bharati University, December 28, 1994 - January 2, 1995.

120. **Mishra, A.** presented a paper on Vacuum Structure in QCD with Quark and Gluon Condensate at the XI DAE HEP Symposium, Viswa Bharati University, December 28, 1994 - January 2, 1995.

121. **Mishra, H.** presented a paper on Effective Potential at Finite Temperature : A Variational Approach at the XI DAE HEP Symposium, Viswa Bharati University, December 28, 1994 - January 2, 1995.

LIBRARY

122. **Bharucha, R.** presented a paper on Aftermath of Library Automation at a seminar on Library Automation and its Aftermath, American Studies Research Centre, Hyderabad, April 5-6 1994.

123. **Bharucha, R.** presented a paper on Services to be offered by ADINET at a seminar on Library Networks and Society, ATIRA, February 25 1995.

124. **Bharucha, R.** presented a paper on Information Needs of Scientists at a seminar on User Needs and User Education, Vallabh Vidyangar, March 1-2 1995.

125. **Patil, R.** presented a paper on ADINET - Network of Ahmedabad Librararies at the IASLIC XVI National Seminar on Networking of Libraries : Problems and Prospects, held at Indian Institute of Technology, Bombay, December 19-22 1994.

ELECTRONICS LABORATORY

126. **Mazumdar, H.S.** presented an **invited** paper on CCD and Computer Vision at the Second Workshop on Experimental Techniques in Space Science and Astronomy, Gujarat University, September 13 1994.

127. **Mazumdar, H.S.** presented an **invited** paper on Neural Network Tool Box at the Workshop on Neural Networks at the Centre for Electronics Design and Technology, Aurangabad, March 28-29 1995.

128. **Pradhan, S.N.** presented a paper on Architecture of CPUs for Digital Signal Processing, at the Silver Jubillee Series, Computer Society of India, Ahmedabad.

Science at PRL in 1994 - 95

The scientific programmes pursued by the Astronomy and Astrophysics division consist of investigations pertaining to the velocity field studies near regions of star formation, short time scale variability of active galactic nuclei, imaging studies of active galaxies and high angular resolution studies of evolved stars. In addition interesting results have been obtained in the latitudinal variation of solar wind and electron density, solar flares and associated magentic field activity. The comet Shoemaker-Levy 9 collision with giant planet Jupiter also attracted the attention of division members during the period of this report. Many results have come out in the first few months of operation of the 1.2m Gurushikhar telescope which became operational in December 1994. The observed image sizes are limited by the atmospheric seeing (**Fig. 1.1**)

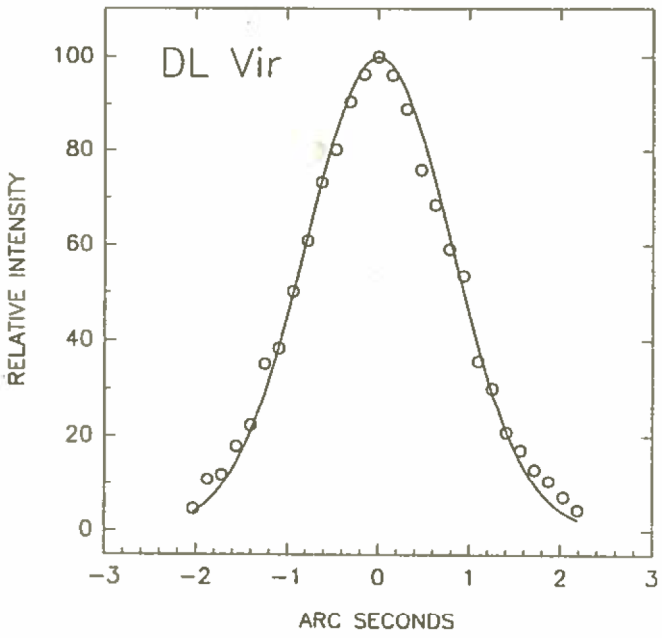


Fig. 1.1. Image profile of a stellar source DL Virginis (V = 6.95). The CCD image was recorded at the f/13 Cassegrain focus of the 1.2m Gurushikhar telescope on April 4 1995 , 1811 hrs UT with an exposure time of 5 seconds. The image size is limited by atmospheric 'seeing' and a Gaussian profile fitted to the data has a full width at half maximum (FWHM) of 1.9 seconds of arc.

OPTICAL AND INFRARED ASTRONOMY

Studies on Velocity Fields in HII Regions Associated with Star Formation

Continuing our efforts in understanding the velocity field structure in HII regions associated with star formation we have observed Orion, Rosette, Lagoon and Trifid nebulae using the Imaging Fabry-Perot Spectrometer (IFPS) at the newly refurbished 1.2m telescope at Gurushikhar Observatory. The velocity field maps in [OIII] 5007A ,Hα , [NII] 6584 A, [SII] 6735A and [OI] 6300A emission lines have been obtained. Several narrow-band filtergrams have also been obtained. The emission regions will be delineated and related to the velocity fields. The spectral resolution lies in the range 0.2 -0.7 A and spatial resolution is 2 arcseconds. An image intensifier-aided guiding system was fabricated and used. Four-quadrant detectors will be soon employed for guiding of the telescope.

The aim of these observations is to (i) find the general velocity patterns and look for multiple components, (ii) detect high-velocity flows around young stellar objects and (iii) find the structure of velocity field around ionization fronts and ionization/excitation mechanism for the ions. The detection of high velocity flows like the one we have found in the Lagoon nebula (**Fig. 1.2**) may enable us to provide evidence for star formation triggered by the outflow from high mass stars.

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

Studies on the Post-Asymptotic Giant Branch Evolution of Intermediate Mass Stars

The process of mass loss in the form of ejection of outer envelopes during the asymptotic giant branch (AGB) and later in the life of an intermediate mass star is not well understood. One of the direct ways to comprehend these processes is to find velocity fields in the Planetary Nebulae (PNe). In addition near infrared photometric and spectroscopic observations of post-AGB stars are useful in obtaining the amount and geometry of the mass loss.

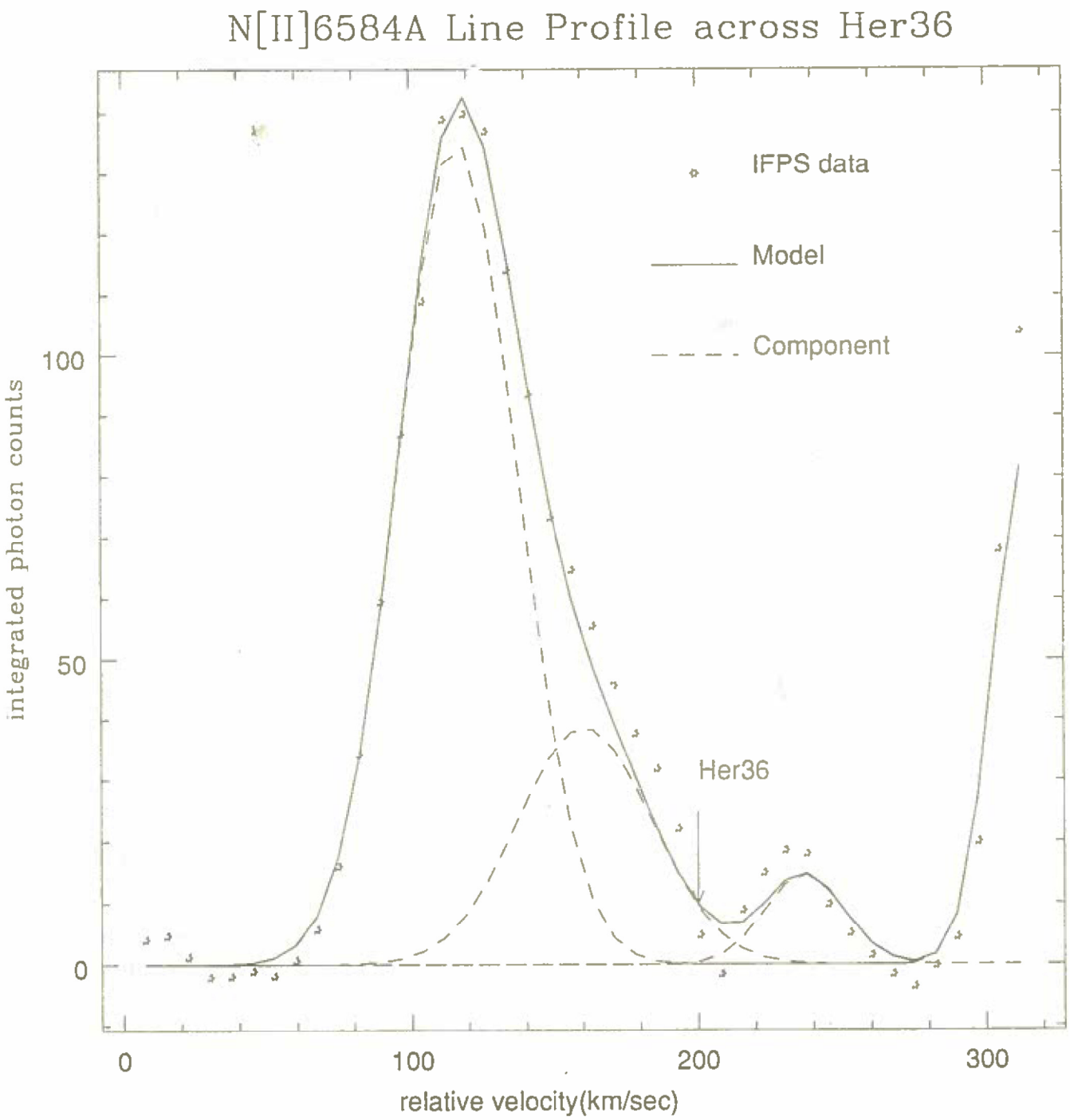


Fig. 1.2. [NII] 6584 A line profile across Herschel 36 in the H II region, Lagoon nebula, observed by using the IFPS at the 1.2 m telescope, Gurushikhar, Mt.Abu. The IFPS data are shown by stars and the multi-gausssian profile model by the full line. The dashed-lines show individual Gaussian components. The small but significant bump on the right side of the star H 36 indicates the presence of a jet-like feature with velocity of about 55 km/s with reference to the ambient medium near the star. The two Gaussians comprising the profile to the left of H 36 suggest multiple flows in certain regions in Lagoon.

Our earlier work concentrated on the study of kinematics of gross morphological features of the PNe using central-fringe-scanning FPS in the optical region. These results showed some important features regarding the kinematics vis-a-vis the dynamical models. Many PNe show a variety of peculiar structures such as filaments, knots or condensations, bi-polar jet-like flows etc. Using our Imaging Fabry-Perot Spectrometer at 1.2m telescope of Gurushikhar we have started a programme to obtain velocity field maps and relate the kinematics of the peculiar structures with gross features. Several PNe notably NGC 1514, NGC 2818 and NGC 4361 have been observed in [OIII] 5007A and Hα lines. Several narrow-band filtergrams in emission lines have also been obtained. Analysis is in progress.

In recent times some objects have been identified as proto-planetary nebulae. Optical spectroscopic and near-infrared photometric observations are planned to study the mass loss process in these objects.

(B.G.Anandarao, N.M.Ashok, D.P.K.Banerjee, N.S.Jog, C.Muthumariappan, H.I.Pandya, R.T.Patel and F.M.Pathan)

Rapid Variability in the Be Stars: An International Campaign on Lambda Eridani

The Be star Lambda Eridani is a B2e type star. Based on the detection of powerful X-ray flare during earlier ROSAT observations of this star an international campaign was conducted during the period 26 February - 1 March 1995. λ Eri was monitored at X-ray wavelengths using ROSAT and ASCA satellites and at optical wavelength - especially in the He I and Hα lines-using ground based telescopes. High resolution Fabry-Perot spectroscopic observations were done from Gurushikhar. The star was found to be in a mild emission phase in Hα (**Fig. 1.3**). Additional observations have been obtained at Rangapur by Dr. G.C. Kilambi and at Kavalur by Dr. K.K. Ghosh. Intercomparison of optical and X-ray data will be done shortly. Dr. Myron Smith, USA, co-ordinated this campaign.

(B.G.Anandarao, A.Chakraborty, N.S.Jog, K.S.B.Manian, C.Muthumariappan, R.T.Patel and F.M.Pathan).

Photopolarimetric Study of BL Lac Objects

Continuing our efforts to detect short time scale variability, we have made observations on some selected BL Lac objects using optical photopolarimeter at the Cassegrain focus of 1.2m telescope of Gurushikhar observatory. Observations were made on OJ287, Mrk421, 3C66 in UBVRI bands. Standard polarimetric stars were also observed. As these were the first polarimetric observations with this newly installed telescope, polarimetric performance of the telescope was evaluated. The combined instrumental polarization of telescope and polarimeter has been estimated to be less than 0.04%, indicating excellent performance of the telescope for polarization observations. The software of the polarimeter was modified to be more user friendly. The aim of this study is to address some important questions in the study of AGNs:

(i) the nature of the central source responsible for the short time scale variability (time scale as low as an hour or smaller).

(ii) the characteristics of the plasma inhomogenieties in the jet.

One of our important findings in the past with polarimetric studies of AGN objects was the detection of short time scale variability. In BL Lac object OJ287, variability with a time scale of 25 minutes was observed earlier. More recent observations on the same object using 2.3 meter VBT at Kavalur show flux and polarization variability on an even shorter time scale of 6.3 minutes. Variability with somewhat longer time scale of 20 minutes has also been observed for Mrk 421.The preliminary analysis of our very recent observations made on Gurushikhar 1.2m telescope confirm the existence of short time scale variability.

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

International Campaign on OJ287

OJ287 shows rapid variability in almost all frequencies from radio to X-rays. To have 24hour coverage over a period of 10 days an international campaign was

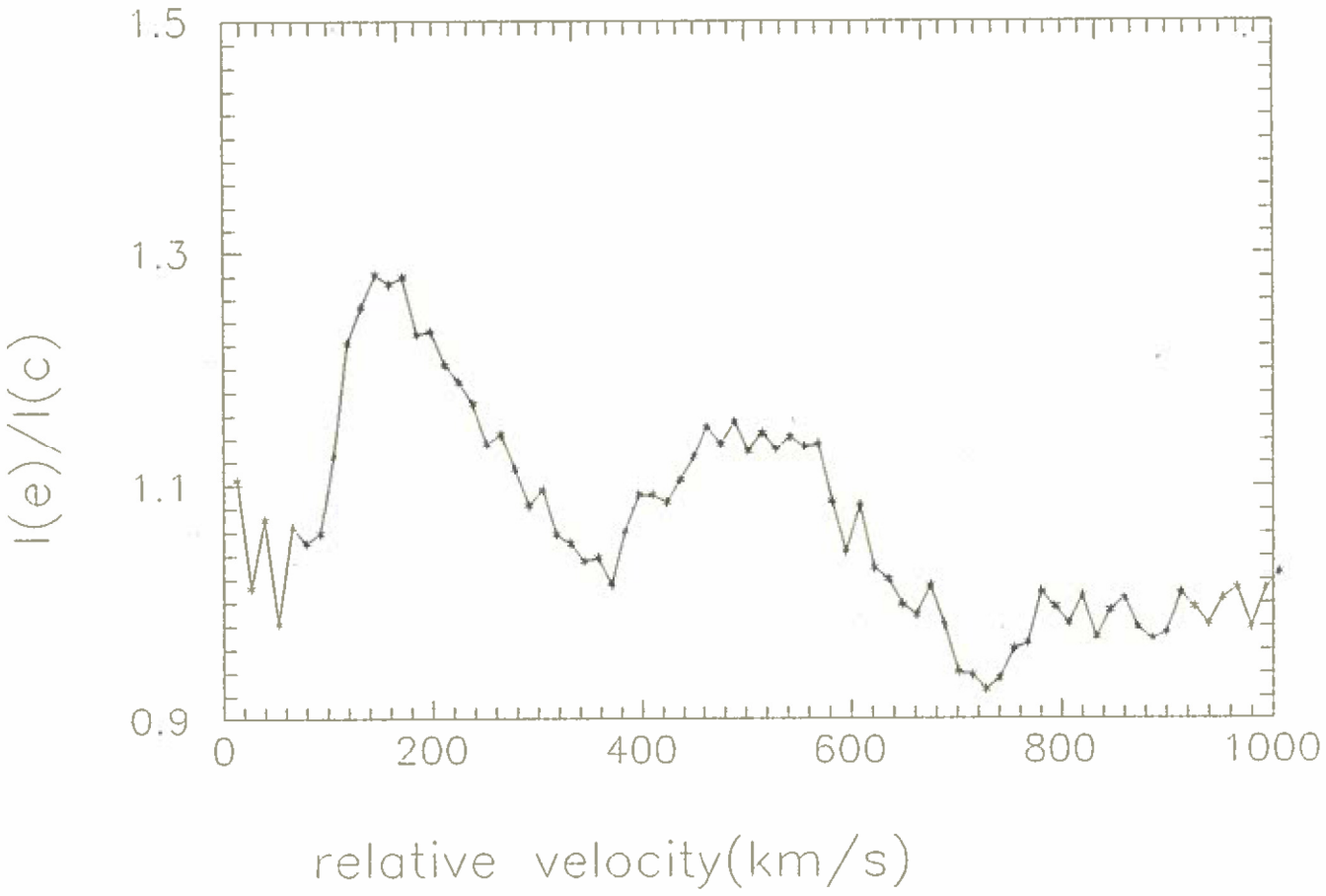


Fig. 1.3. H alpha line profile (emission line intensity/continuum intensity) showing a mild emission episode in the Be star Lambda Eridani on 28 February 1995. These observations, which form a part of an international campaign, were made at Mt.Abu using the central-fringe scanning FPS.

organized by Turku group during January 26-February 6, 1995. 3C66 was also included in the list. We carried out photopolarimetric observations on OJ287 and 3C66 using PRL optical photopolarimeter on newly installed 1.2m IR telescope at Gurushikhar.

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

Broad Band Photometric Study of Active Galaxies

The recent observational studies of nuclear activity in AGNs and star bursts in active galaxies have shown correlations between their properties and similarities in their environment suggesting some mechanistic evolutionary link between the two phenomena. Conventional black hole accretion models for AGN have difficulties in storing fuel close enough to the black hole and yet remain optically thin as required by the observed rapid variability of the continuum. These difficulties led to the reconsideration of the possible presence in AGN of a young cluster of mass-losing stars and supernovae either in the immediate vicinity of a central black hole or in isolation in a more extended region.

In order to understand the relationship between nuclear activity and vigorous star formation activity (star bursts), broad band (UBVRI) imaging studies have been initiated to understand morphology vis-a-vis star burst activity in galaxies. A number of galaxies were observed on 1m telescope of U.P. State Observatory,

Nainital with a liquid nitrogen cooled CCD camera of UPSO. The work is done in collaboration with Drs. J.B.Srivastava and B.S. Rautela from UPSO, Nainital.

Broad band BVRI images of galaxies Mrk35, Mrk700, Mrk769, Mrk 799, Mrk 960, Mrk 1043, Mrk 1083 along with the standard stars from Landolt list were taken. All the analysis work is being done at PRL with IRAF package. Some interesting results are as follows:

Surface photometry of galaxies was performed and their colour maps were constructed. The contour maps of Mrk 35 were superposed on the galaxy images in BVRI bands (**Fig. 1.4**). Contours show deviations from a smooth geometry. In SE region a jet like feature is seen which is more prominent in R image. The high frequency images in BVRI bands show complex structures (**Fig. 1.5**). The hot spots may be giant clusters (high star forming regions). We also notice a bar like structure in the nuclear region. Such bars may be responsible for star burst activity close to the nuclear region. Photometry of individual hot spots has been done and their inter comparison made. Similar study has been made on Mrk 799. Analysis on other galaxies is in progress.

(U. C. Joshi and Aparna Chitre)

PRL CCD Camera

The performance of liquid nitrogen cooled CCD camera developed at PRL was evaluated using 1.2m telescope. Several improvements in both hardware and software have been done. The double correlated data transmitter-receiver circuits and 16 sit A/D converter have been incorporated. The camera works in slow scan mode to reduce the readout noise, the typical value being 5-6e^- per ADU. Subframes, whose size and location can be selected by the user, provide fast readout for fine focusing; the image is displayed using super VGA card with a provision for intensity readout. Alongwith the image data, the telescope related parameters are also stored. Image of some galaxies have been taken using 1.2m telescope.

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

Near Infrared Polarimeter for Astrophysical Studies

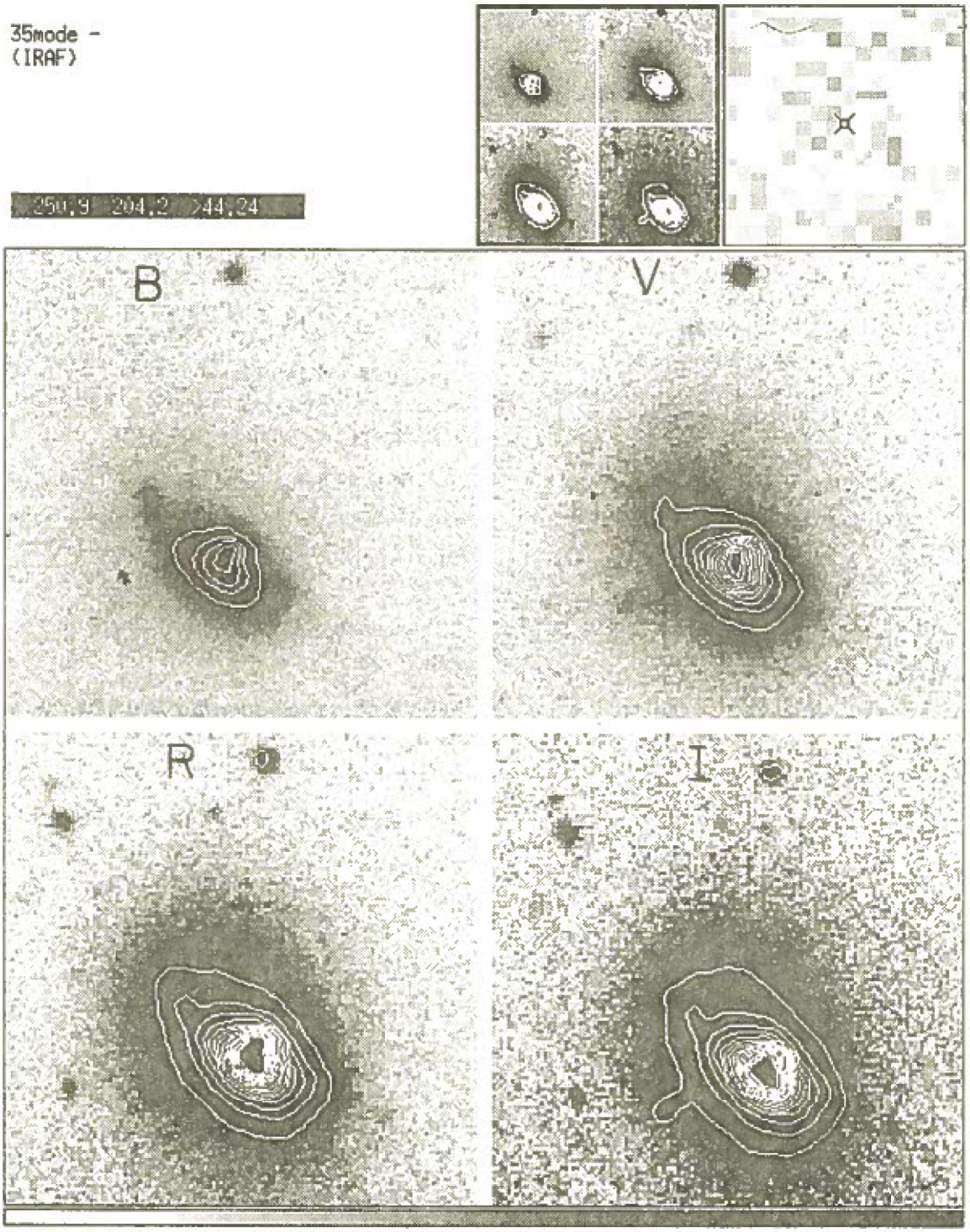
A state of art near infrared photopolarimeter developed in PRL is now operational. The instrument is fully computer controlled and gives online results. A rotating super achromatic Pancharatnam half-wave retarder modulates the signal and the modulated signal passes through the Foster prism through which the light beam is split into two perpendicular beams. The InSb detector operating at liquid nitrogen temperature is placed in one beam and the second beam is used for visual monitoring purpose. A tertiary vibrating mirror is used for chopping the light-signal for eliminating background sky noise. For calibrating and performance checking at the telescope provision has been made to insert Glan prism to provide 100% polarized beam.

The instrument was tested at 1.2m telescope. Observations were made in JHK bands on some standard stars, zero polarization stars and programme stars. The performance of the instrument is quite satisfactory.

(U.C. Joshi, K.S.B. Manian, J.S. Chauhan, Aparna Chitre and V. Shah)

High Angular Resolution Studies in the Near Infrared by Lunar Occultations at the Gurushikhar Telescope

The program of High Angular Resolution observations of bright Infrared sources by the technique of lunar occultations in the K band (2.2 microns) greatly benefitted with the availability of the Gurushikhar 1.2 m telescope from December 1994. The occultation method being event based and requiring adequate follow up photometry is telescope time intensive. During the last few years, only a few occultation observations could be carried out from Kavalur because of limited telescope time availability and cloudy conditions prevailing there. The first scientific observation with the 1.2 m Telescope was the occultation of the infrared source IRC-10557 at 2.2 microns on December 7, 1994. During the last six months of operation at Gurushikhar over a dozen occultation events have been successfully observed. A data analysis software package for the occultation light curves has been developed, tested and put into operation. A



Fig, 1.4. Contour maps of Mrk 35 superposed on its images in BVRI bands. The deviations from a smooth geometry are clearly seen.

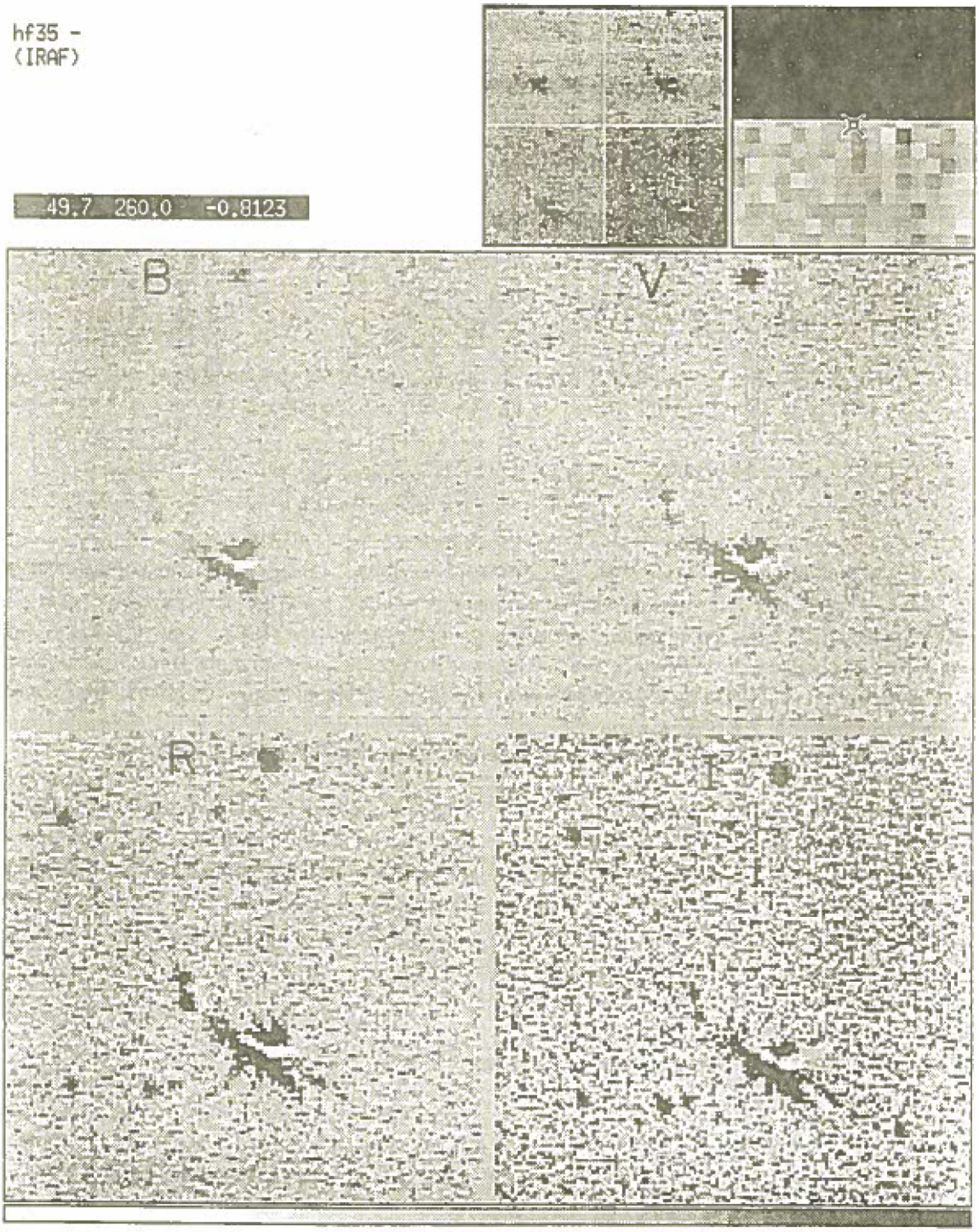


Fig. 1.5 The high frequency images of Mrk 35 in BVRI bands showing complex structures.

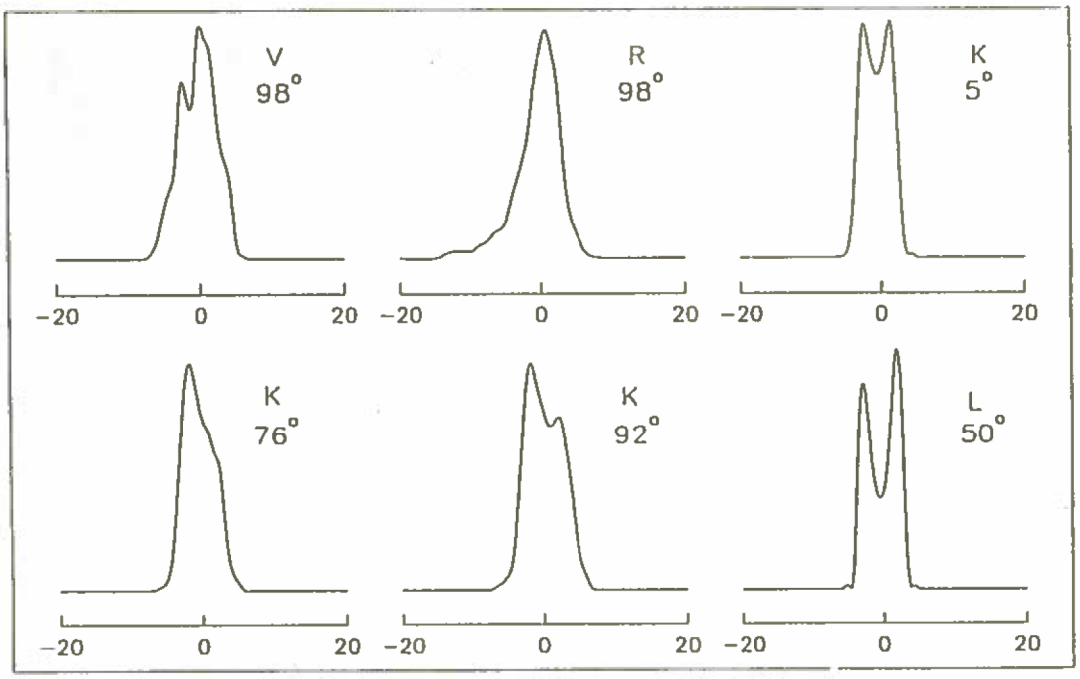


Fig. 1.6. The brightness profiles for the Carbon Star TX Psc, constructed using a model independent method for different occultation chords across the sources denoted by position angles. Horizontal axes are in milliarcseconds and y axes are in arbitrary intensity units. At the distance to TX Psc, 1 milliarcsecond corresponds to 0.3 Astronomical Units. Position angle 76 refers to the occultation observed at Gurushikhar while other position angles refer to occultations of TX Psc at other observatories (Calern, France, 98 : Tirgo, Switzerland 92 : Wyoming IR Observatory, USA, 5 : Calar Alto, Spain, 50). The asymmetric profiles in K(2.2 microns) and L bands (3.6 microns) show the presence of warm circumstellar dust around TX Psc.

model independent analysis for the recovery of the one dimensional source structure from the occultation light curves has become possible for sources with good signal to noise ratio (S/N >50). This has been applied successfully to sources TX Psc, TV Gem , IRC 20073. Realising the importance of multi wavelength occultations from the TX Psc campaign, efforts are currently being directed at developing a two channel occultation photometer operating in the K (2.2 microns) and L (3.6 microns) wavelength bands.

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

Asymmetric Circumstellar Structure around Carbon Star TX Psc

TX Psc is a N3 type bright carbon star. Carbon stars are generally characterized by extremely red colours, low effective and colour temperatures and irregular photometric variability. There has been considerable debate on the circumstellar environment of carbon stars. Model calculations had predicted thick extended dust shells at temperatures of 750 K around carbon stars like T Cnc. Actual occultation observations had detected only weak shells.

The question as to whether a hotter carbon star like TX Psc will exhibit a shell or not was open to investigation. An international lunar occultation campaign was conducted in 1993-94 to study at high angular resolution, the source environment around TX Psc. PRL participated actively in this campaign and contributed two occultation near Infrared light curves. The campaign has clearly established substantial departures from the simple model of a circular disk which has been interpreted as due to the presence of warm dust adjacent to the stellar photosphere within a few stellar radii (**Fig. 1.6**). The dust

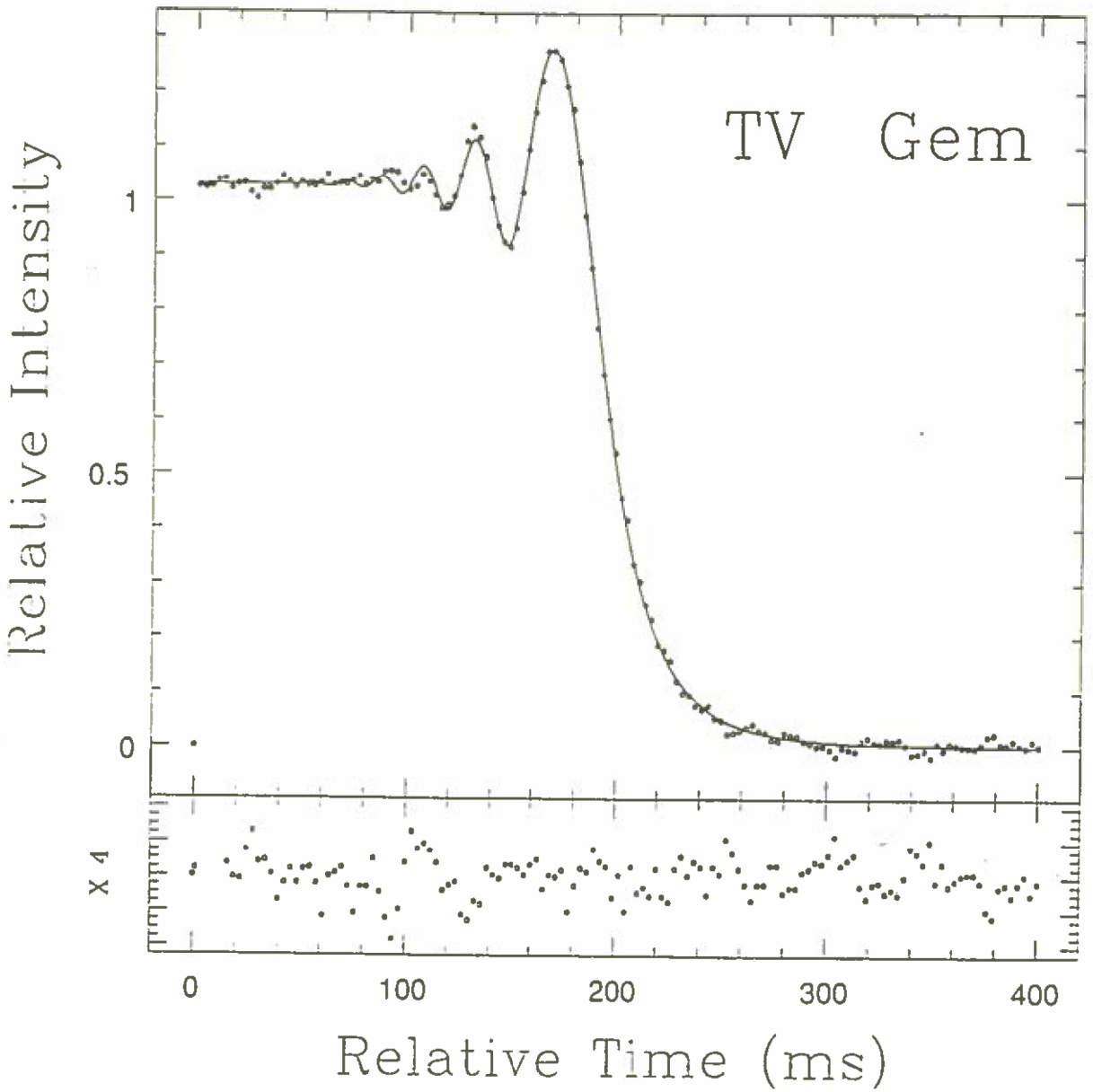


Fig. 1.7. Occultation light curve (dots) of TV Gem observed with Kavalur 0.75 m telescope at 2.2 microns on March 30, 1992. The solid line is the model fit to the data by model independent algorithm. Lower panel shows the residual of the model fit magnified by a factor of 4. Source size derived : 4.7± 0.3 milliarcseconds.

distribution around TX Psc, revealed by the different occultation chords appears to be highly asymmetric.

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

TV Gem and its Circumstellar Region

TV Gem (IRC 20134) is an oxygen rich supergiant (M1 Iab). It exhibits semi regular pulsations with an approximate period of 182 days. IUE spectroscopy in the spectral range 1250-1900 A and UBVRI photometry are consistent with a B 3.5 IV campanion around the M1 primary. Presence of circumstellar gaseous envelope is confirmed by CO(1-0) and CO(2-1) line observations. The low resolution spectrum (LRS) of IRAS shows a strong 9.7 μm silicate feature in emission, indicating the presence of hot dust in the circumstellar region.

From our occultation observations (**Fig. 1.7**) we clearly resolve the central star and determine its angular size to be ~ 4.7 ± 0.3 milliarc seconds (mas). In addition to the stellar component, the model independent method of analysis requires, for a completely satisfactory fit to the observed light curve, a circumstellar shell of size ~ 100 mas (**Fig. 1.8**). The star + shell model is consistent with the IR excess seen in the photometric data longward of 2.2 μm.

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

Observations of Reappearance Events in Lunar Occultations

An important advancement in our observational capability was made with successful observations of several reappearance events on the dark limb of the moon. Reappearance events enhance the number of sources that can be observed by the lunar occultation technique. Observations of reappearance events require the telescope to follow the star precisely even when it is behind the lunar disk for about an hour which is difficult to achieve at the level of a few arcseconds at different telescope orientations. By pointing to nearby stars which are not occulted and exactly offsetting the telescope it has been possible to correct for minor errors in telescope tracking and thereby successfully observe the program star as it emerges from behind the limb of the moon. Reappearance of the following sources were successfully observed - IRC+10197 (K=2.24); IRC-20374 (K=2.26); IRC-10301 (K=1.52) (**Fig. 1.9**); IRC-10305(K=2.6); IRC-20470 (K=2.36); IRC-20474 (K=2.44). Several of these occultations have been observed well after sunrise emphasizing thereby the capability of near Infrared (2.2 micron) observations during daytime from Gurushikhar.

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

Nova Aquilae 1995

Infrared observations of novae provide a direct means of detecting formation of dust in nova ejecta and studying its subsequent evolution.

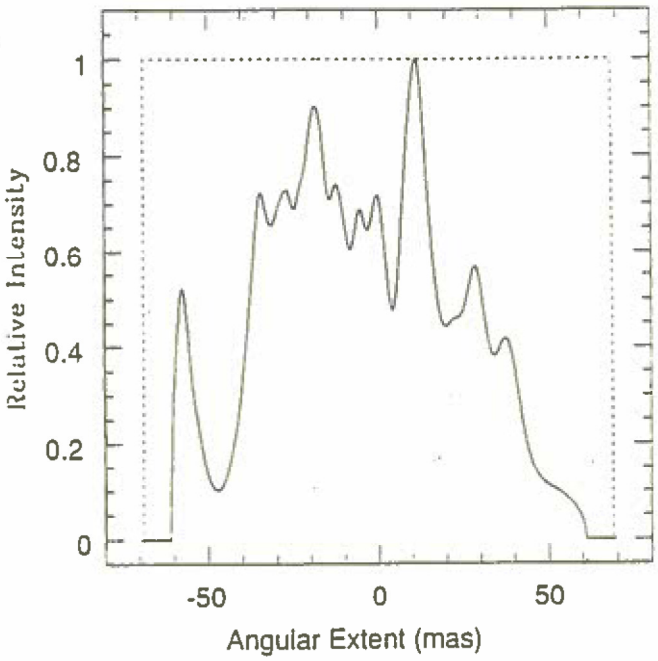


Fig. 1.8. Brightness profile of the extended component of TV Gem derived with the model-independent algorithm (solid line). The dotted line shows the initial guess profile. The zero in X axis marks the position of the central star.

On 8th February 1995 Nova Acquilae 1995 was discovered by Takamizawa at a visual magnitude of 8.0. PRL IR observations at 1.2 m Gurushikhar telescope began on 16th February 1995, and continued till the first week of April 1995 when the nova became too faint to be observable. During this period JHK broad-band photometry (1 - 2.5 microns) was carried out (**Fig. 1.10**). Color temperatures have been derived using the H (1.65 micron) and K (2.2 microns) filter observations. These temperatures, attributed to the dust grains formed in the cooling phase of the nova range from 1700 K on day 8 to ~ 1200 K on day 30 (**Fig. 1.11**). The cooling curve of the nova appears distinctly different from that of Nova Herculis 1991 observed by us earlier.

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

Angular Chopping for Extended IR Sources

In IR observations, due to the large background from the sky, telescope etc., it is necessary to sample the star + sky and nearby sky separately several times per

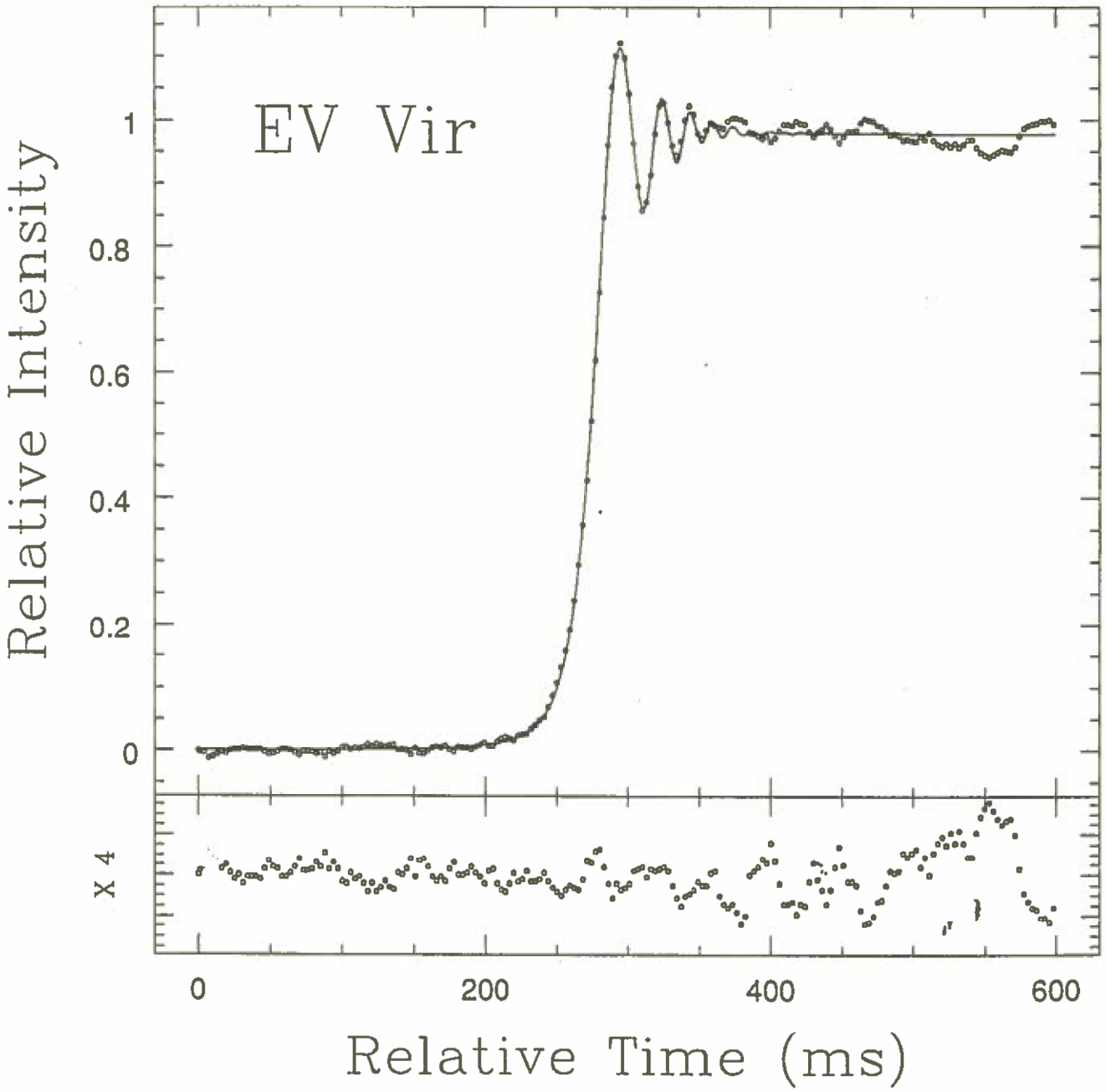


Fig. 1.9. Reappearance event (dots) of EV Vir observed on March 19, 1995 with Gurushikhar 1.2 m telescope at 2.2 microns. The solid line is a model fit to the data using nonlinear least square method.

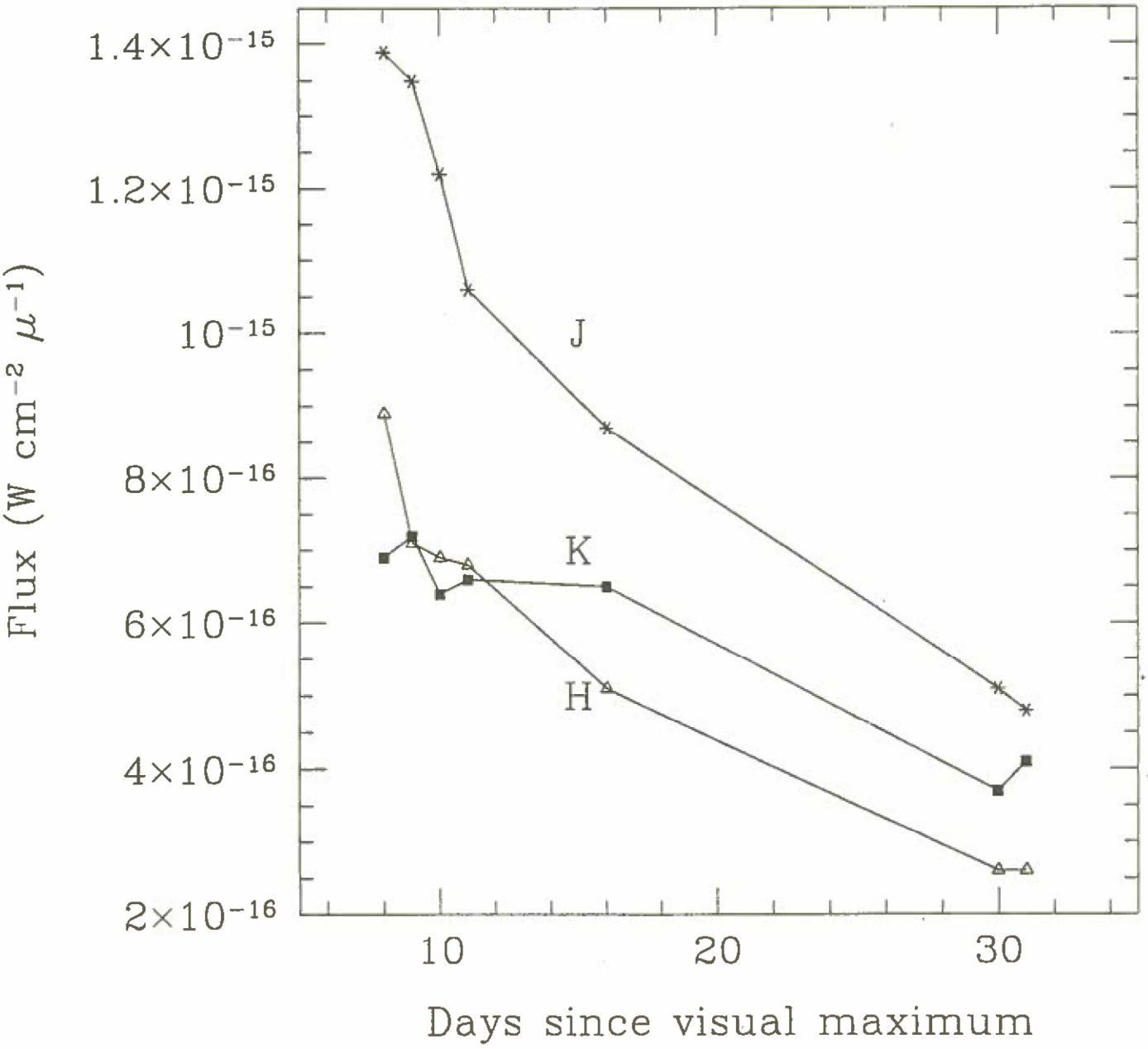


Fig. 1.10. Light curve of Nova Aquilae 1995 in JHK near infrared filter bands.

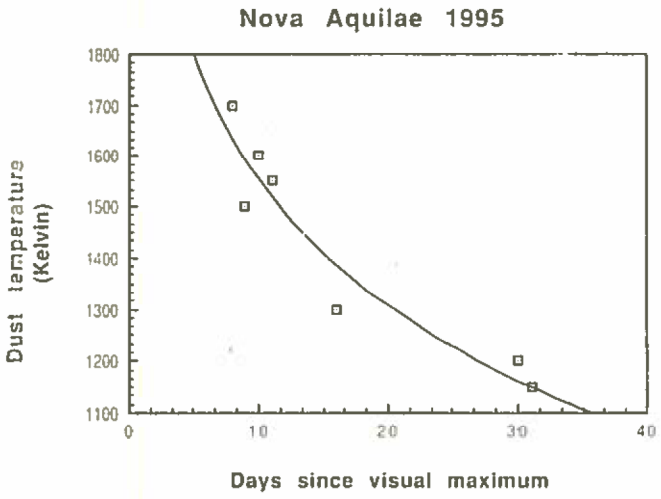


Fig. 1.11. Temporal evolution of dust in Nova Acquilae 1995. The dust temperature falls off as ~ $T^{-1/4}$ which is shown by the continuous curve.

second (typically 15 Hz) and then detect the small difference signal due to the star by phase sensitive detection techniques. In the absence of a vibrating secondary mirror at Indian telescopes, this 'Sky Chopping' has been accomplished by a vibrating tertiary plane mirror mounted at 45° to the incoming beam. A main drawback of this tertiary mirror chopping is its limited 'throw' in the sky typically ~ 25 arcseconds which while adequate for stellar (point) sources, is not sufficient for detecting extended sources like dark interstellar clouds, or comets.

In order to increase angular displacement (the throw), an angular chopping technique has been experimented and has proved successful. Several arcminute separation of the two beams are readily achieved at low frequencies, which will permit extended sources to be studied at Gurushikhar even without the vibrating secondary mirror. Angular chopping at high frequencies (upto ~ 1 KHz) is also being experimented upon with the goal of pushing the lunar occultation techique to fainter sources (K > 6) to obtain good quality, high S/N occultation light curves, from which source structure information can be determined.

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

Fourier Transform Spectrometer

The interferometric path difference control system for the F.T.S. needs a clean spatially filtered laser beam. The system for spatial filtering and subsequent beam expansion and beam shaping has been completed.

The stability of the laser interference fringes with the components mounted on the coude pier were tested together with the modulated intensity signal at 150 KHz; and was found to be satisfactory. Now only optical assembly on the coude pier remains to be done.

(S.D.Rawat, D.V.Subhedar, P.K.Kikani and J.N.Desai)

The Collision of Comet Shoemaker-Levy9 (1993e) with Jupiter - Optical Observations from Jaisalmar

The encounter with Jupiter of Comet ShoeMaker-Levy 9 in its fragmented form during the week July 16-July 22, 1994 was a very rare celestial event, happening perhaps once in a thousand years. In that sense this generation is fortunate to have been witness to such an event wherein cometary fragments, several kms in extent, have slammed at velocities of ~ 60 km/sec into the gaseous mass of Jupiter. The cometary encounter with the giant planet Jupiter provided a very good opportunity to study the nature of the cometary material and the effects of dissipation of the large collisional energy in the rapidly rotating atmosphere of the planet.

An observational campaign was conducted at Jaisalmar in West Rajasthan during the period July 17-21, 1994 to study the effects of Comet Shoemaker-Levy 9 collision with Jupiter. The selection of Jaisalmar as the observing site was done because it is located in the Thar desert and therefore likely to be less affected by monsoon conditions prevailing then over most parts of the Indian peninsula. A 20 cm reflector telescope was set up alongwith CCD cameras for obtaining digital images of Jupiter. Out of a total of 21 impacts of the cometary fragments, 3 impact timings were such that Jupiter was conveniently located in the night sky for optical observations from Jaisalmar. A sequence of images have been taken covering these three events on July 17, 20 and 21. The images taken on July 21, 1994 clearly show atleast two impact sites as dark regions on the bright disk of

Jupiter. Some image processing work to enhance the impact site images and see their temporal development over a period of a few hours immediately following the impacts are being carried out.

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

RADIO ASTRONOMY AND INTERPLANETARY SCINTILLATIONS

Encounter of Comet Shoemaker-Levy 9 with Jupiter - Radio Observations

During the encounter of the fragments of comet Shoemaker-Levy 9 (SL-9) with Jupiter we made radio observations of this event at 22 MHz, 103 MHz and 4.15 GHz. The latter observations (at 4.15 GHz) were joint efforts with the Space Applications Centre, Ahmedabad. No observable effects were seen at 22 MHz and 103 MHz, where as microwave emission at 4.15 GHz showed some very interesting features. The microwave emission showed an appreciable enhancement after the impacts of first five fragments. This enhanced continuum remained at this level for the next five days. On July 25 the continuum returned to almost the normal level. The fragments K, N, P2 and S were seen to give short duration (10-40 minutes) bursts at 4.15 GHz. The fragments K and N produced three enhancements each in the microwave flux (**Fig. 1.12**).

(M.R. Deshpande, O.P.N. Calla, H. O. Vats, N.M. Vadher, V. Sukumaran and B.M. Darji)

Periodic Oscillations Produced by K-fragments in the Microwave Emission of Jupiter

The K-fragment of SL-9 was predicted to impact Jupiter on July 19, 1994 at 10h 30m UT (there could be an uncertainty of ±3 m). Based on the first view, after impact it has been classified as class 1 having a dark region < 10,000 km. This class of impacts have associated with them, large ejecta and probably multiple waves. We made observations of this event and found that at 10h 13m 25s UT the microwave emission showed almost a periodic variation. The periodic variation has a frequency of ~ 0.3 Hz which gradually increased to become ~ 0.8 Hz at around 10h 20m UT (**Fig. 1.13**). The frequency of periodic variation reduces back to ~ 0.3 Hz by about 10h 30m. However, the periodic oscillation persisted upto ~11h UT.

In addition to the periodic variations there are substantial enhancement in the microwave continuum at 10h 15m 12s UT and 10h 24m 06s UT and aperiodic variations having timescales in the range of minutes. The variations of minute timescale are perhaps caused by the gravity waves. The periodic variation can be due to the beaming effect of the synchrotron emission from the Jupiter's magnetosphere. The observations are unique and more work is needed to understand the mechanism of such a radio emission.

(H. O. Vats, M.R. Deshpande, N.M.Vadher, O.P.N. Calla and Chhaya Shah)

Solar Wind Acceleration

The solar wind measurement by interplanetary scintillations method is indirect and gives a measure of weighted average plasma flow in the vicinity of the point of closest approach of the sun to the line of sight from the observer to the radio source used. The solar plasma basically passes through two zones: (1) region close to the Sun, where the solar plasma is accelerated and (2) the region beyond ~20 solar radii from the Sun, where solar plasma normally flows with almost constant speed. Most of the interplanetary scintillation measurements of solar wind are in the latter region. Using the above assumption we obtain the site of origin of the plasma flow for particular observation and also an average acceleration of the solar plasma in the region (1) close to the Sun. These acceleration estimates are being compared with optical and X-ray features on the solar surface. This ongoing study should yield better understanding of the plasma dynamics close to the Sun.

(H. O. Vats, M. Mehta and M.R. Deshpande)

Cross-correlation of Thaltej and Rajkot IPS Data

We are preparing cross-correlogram of the IPS data recorded simultaneously by the radio telescopes at

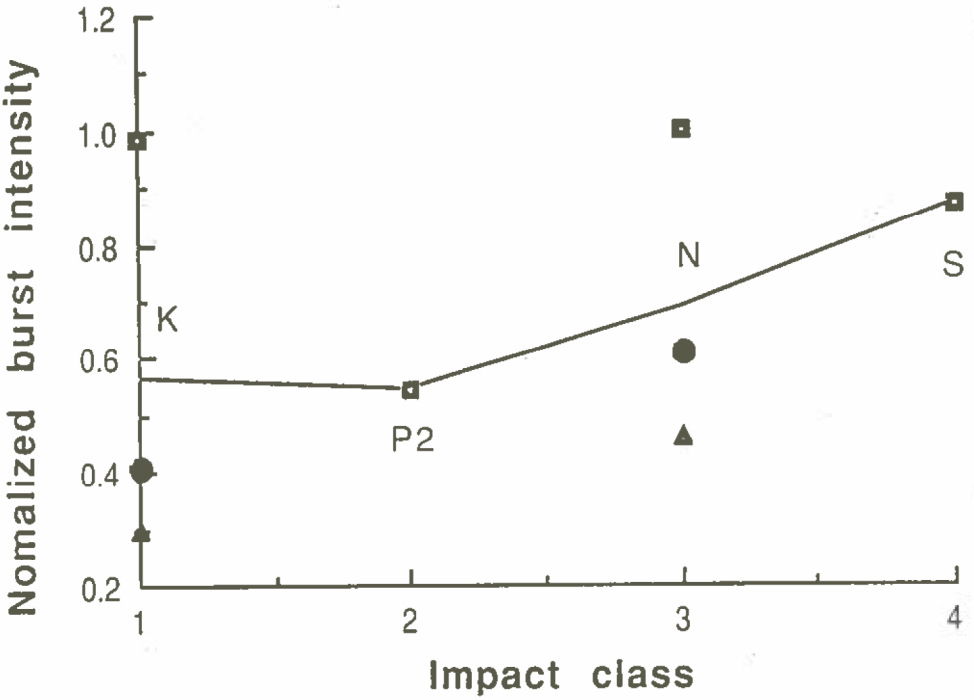


Fig. 1.12 Comparison of normalised burst intensity of Jupiter at Microwave with the impact class of K, N, P2 and S fragments of Comet Shoemaker - Levy 9.

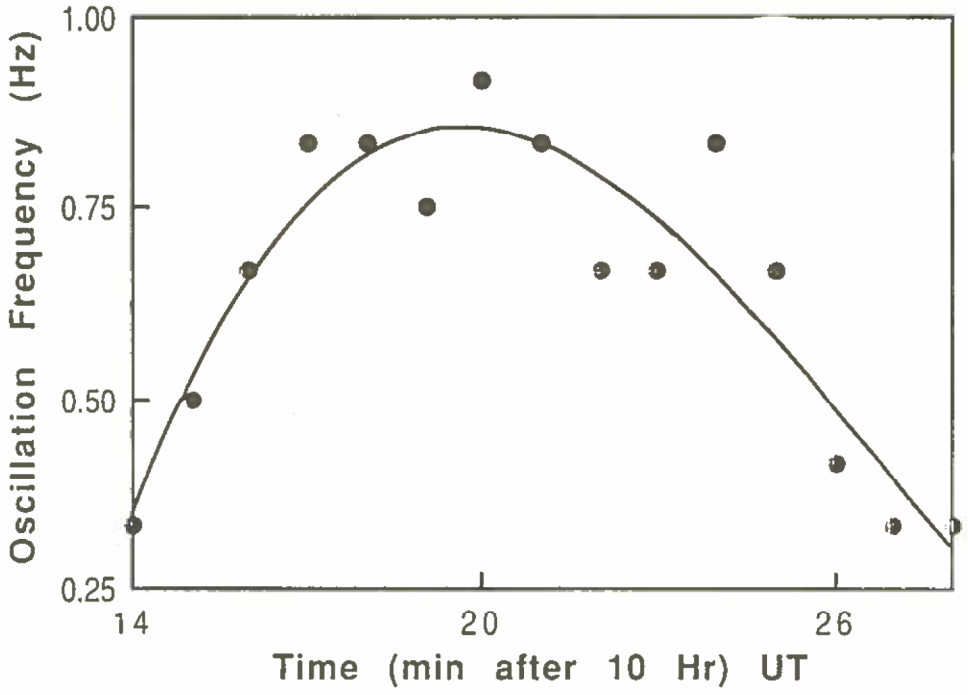


Fig. 1.13 Illustrating the temporal variation of frequency of the peculiar oscillations observed during the impact of K - fragment of Shoemaker - Levy 9 on Jupiter.

Thaltej and Rajkot. This work is being pursued to examine whether a bi-modal model of the solar wind is appropriate or not. The bi-modal model of the solar wind suggests that the wind consists of two components; fast and slow, with little or no intermediate speed. The preliminary analysis so far indicates that there are two types of cases; (1) single dominant speed in the heliosphere and (2) multiple flows giving rise to several peaks in the correlogram. This work will require considerably more simulation and analysis. Further work is in progress.

(H. O. Vats, M.R. Deshpande, K.J. Shah, S.H. Doshi, A.H. Desai and S.L. Kayasth)

Solar Radio Burst (Type III)

Type III radio bursts are a form of sporadic solar radio emission originating throughout the solar corona. Their observations provide information about the magneto-hydro-dynamic processes in the solar corona. It is believed that a stream of sub-relativistic electrons accelerated through the corona excite the radio bursts at the frequency corresponding to the local plasma frequency. For an event of September 30, 1993, we attempted to estimate the velocity of the streams (**Fig.1.14**). In this analysis we used the data recorded at Rajkot and Thaltej radio telescopes and HiRAS (Japan). The study of this solar burst reveals that it consists of a group of four

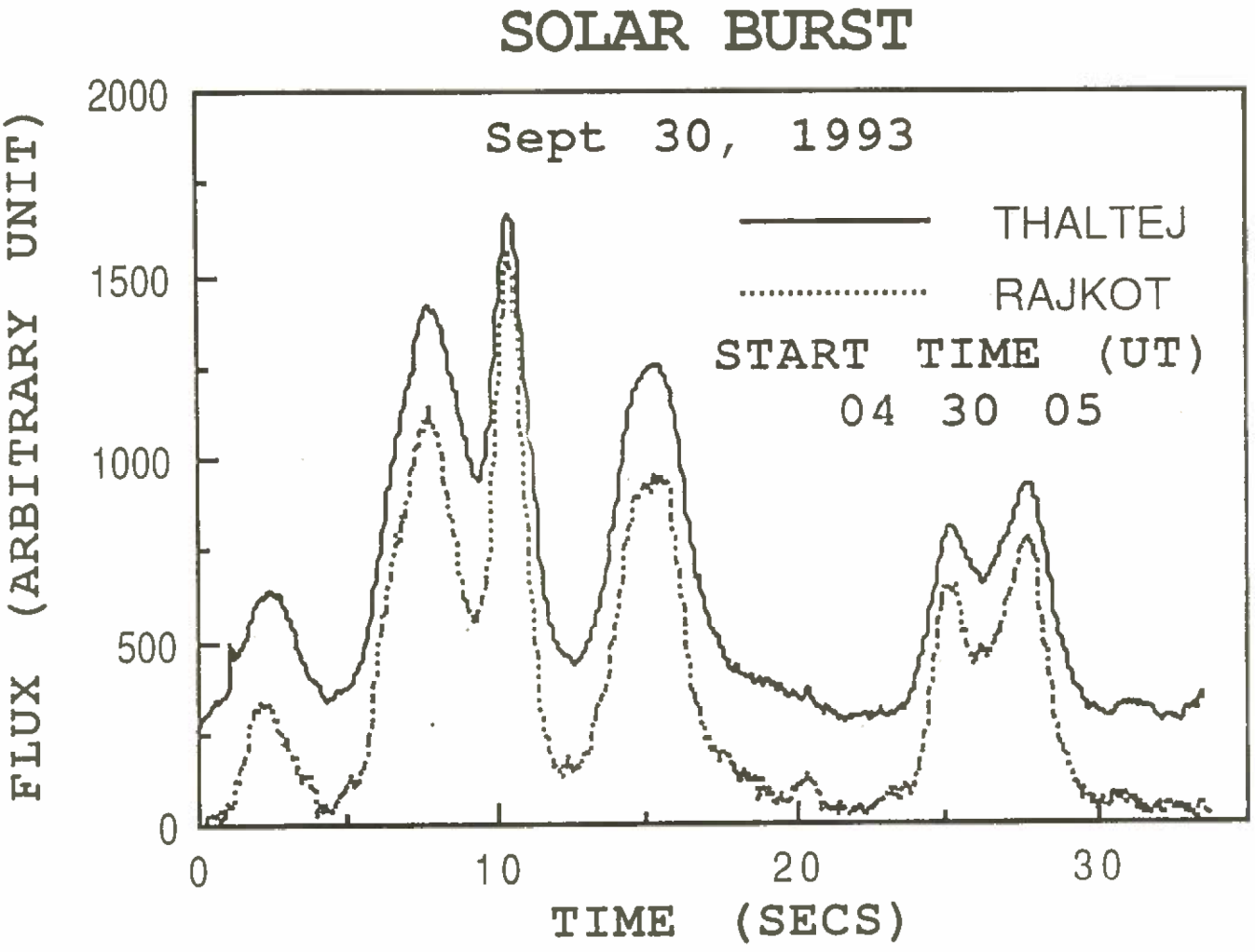


Fig. 1.14 Temporal profiles of Thaltej and Rajkot recordings of Solar Burst on September 30, 1993.

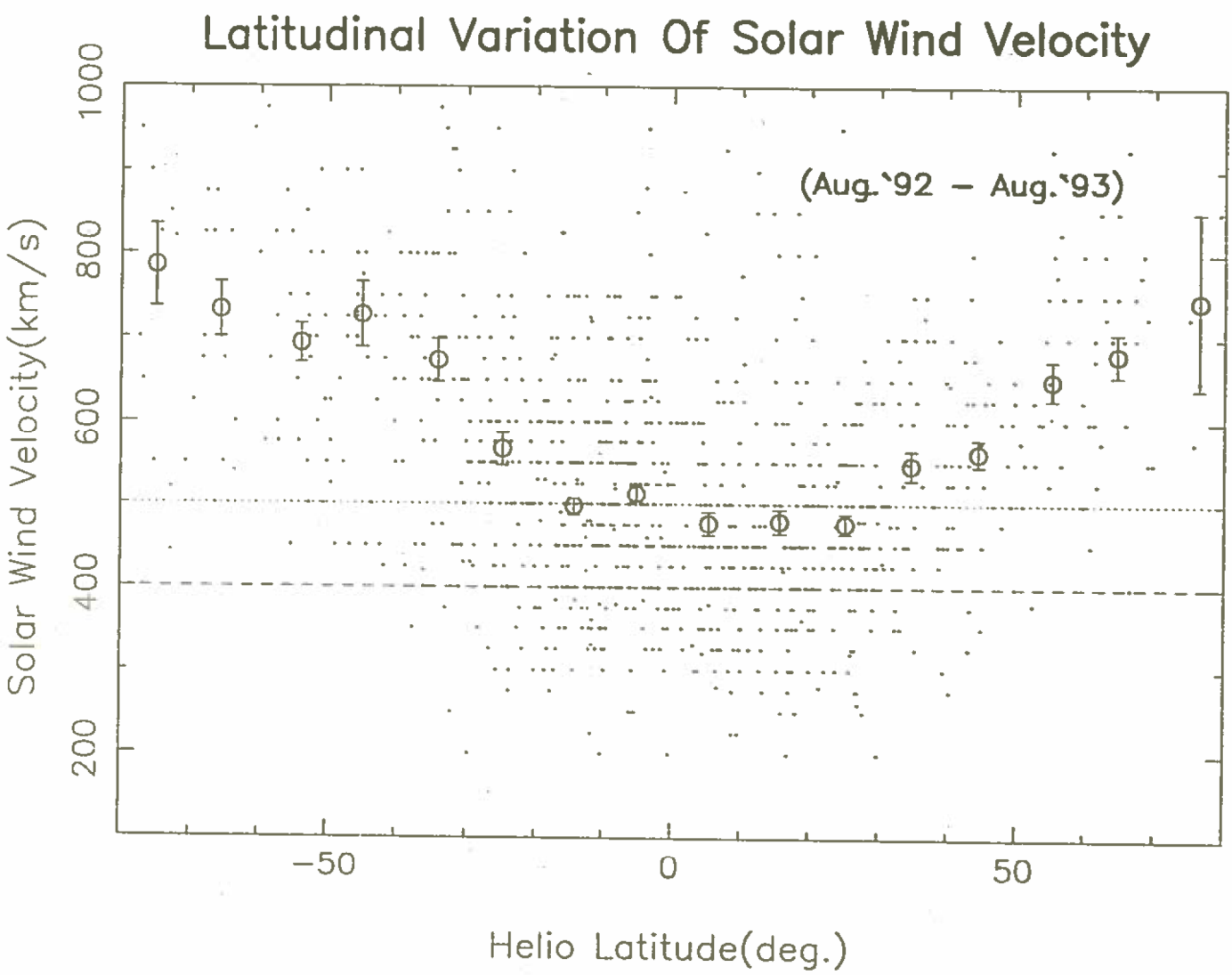


Fig. 1.15. The individual (dots) and mean velocities in 10 bins (open circles) of the solar wind

sub-events having time period of ~ 2 to 10 seconds. Assuming that this sporadic emission is due to a fast moving energetic particles in the solar corona, the speed of the particles seems to be in the range of 0.1 to 0.3 c (c- velocity of light). These results are in agreement with other investigations; however there are situations of large frequency drift and negative frequency drift which require further investigations.

(H. O. Vats, M.R. Deshpande, K.N. Iyer and K.J. Shah)

Latitudinal Variation of Observed Solar Wind Velocities

Single station solar wind velocity measurements using the Ooty Radio Telescope (ORT) in India (operating at 327 MHz) were carried out during the period August 1992 to August 1993. Interplanetary scintillation (IPS) observations on a large number of compact radio sources covering a latitudinal range of ~ $\pm 80^{\circ}$ were used to derive solar wind velocities using the method of fitting a power law model to the observed IPS spectra. The data showed a velocity versus heliographic latitude pattern which is similar to that reported by Rickett and Coles

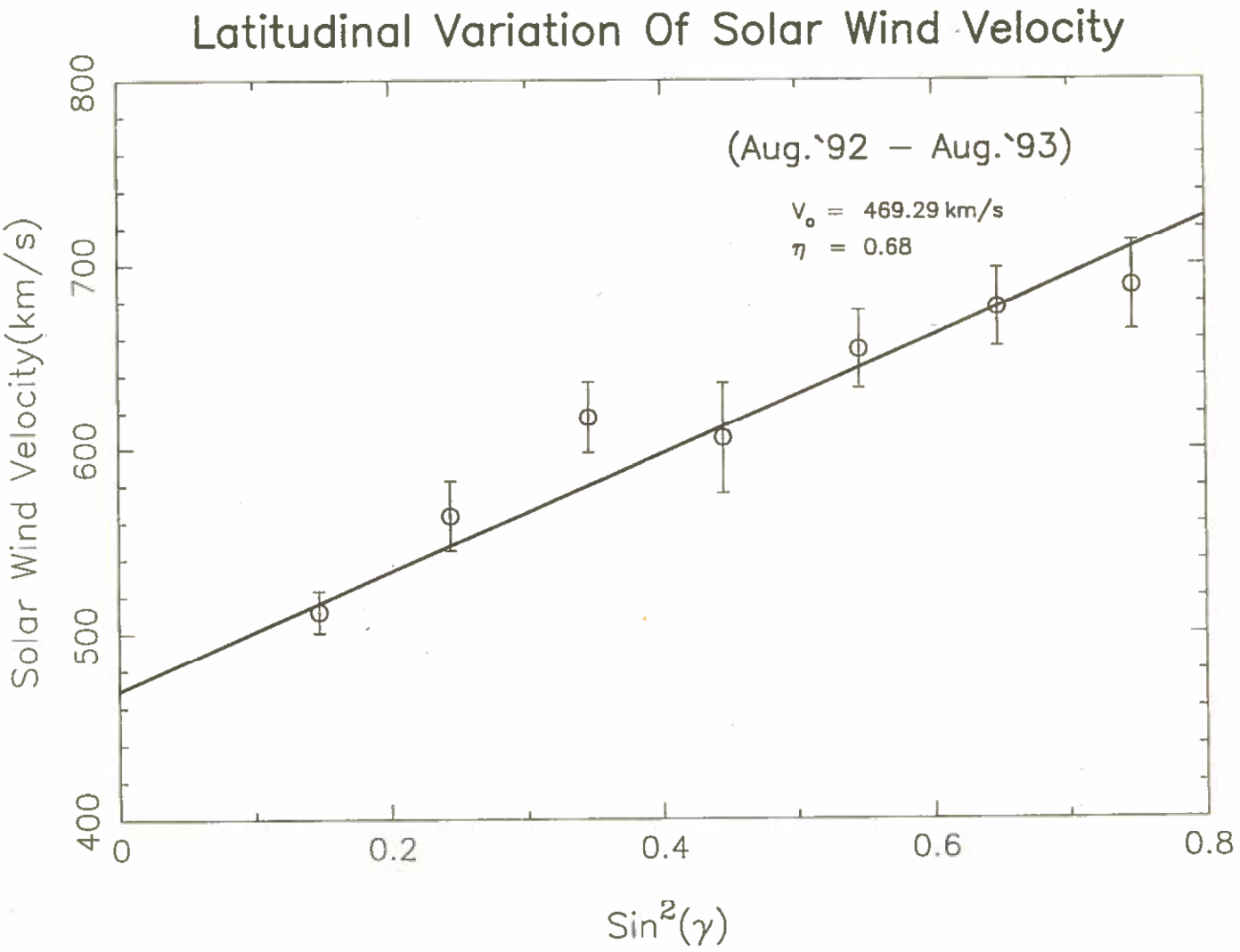


Fig. 1.16. The latitudinal variation of solar wind velocity - γ is the heliographic latitude.

(1991) for the 1981-1982 period. However, the average of the measured equatorial velocities were higher, being about 470 km s^{-1} compared to their value of 400 km s^{-1}. The distribution of electron density variations ΔN_e between $50R_\odot$ and $90R_\odot$ was also determined and it was found that ΔN_e was about 30% less at the poles as compared to the equator.

The velocities, determined from spectra with S/N greater than 20 db and $\varepsilon \geq 15^\circ$ are plotted as a function of heliographic latitude, for each observation. The individual velocity measurements are shown by small dots, while the large open circles represent the mean velocities in each 10° bin of latitude (**Fig. 1.15**). The error bars are $\pm 1\sigma$ and are weighted by the number of points in each bin. It can be seen that the velocities begin to increase beyond ~ 10° on either side of the equator, from ~ 450 km s^{-1} to reach a value of ~ 800 kms^{-1}. The average equatorial velocity V_0 and the gradient of velocity increase can be determined by using the simple empirical relation $V = V_0(1+\eta \sin^2 \gamma)$ where, γ is the heliographic latitude and η is called the activity factor and varies with solar cycle. The straight line fit, shown in **Fig.1.16** gives V_0 = 469 km s^{-1}. The factor η is equal to 0.68 and the velocity gradient over 90° of latitude is 3.6 km s^{-1} deg^{-1} . These values are in agreement with the determinations of annual averages for the same parameters for the declining period of the

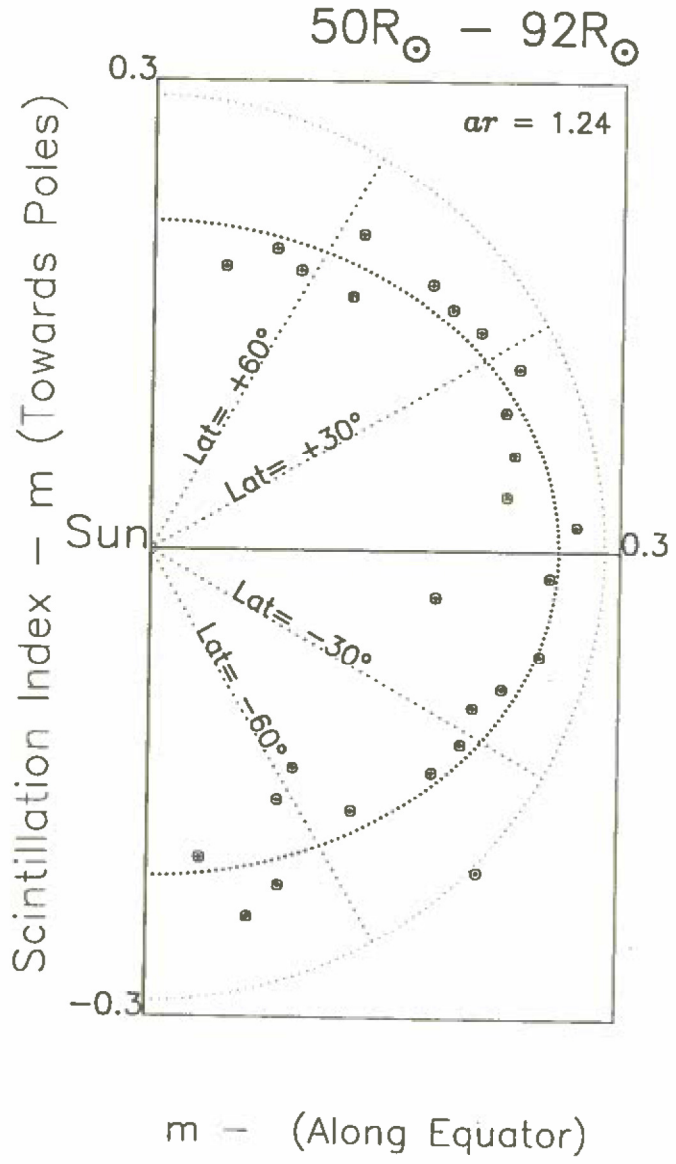


Fig. 1.17. The polar plot of scintillation index m as a function of heliographic latitude.

previous cycle; however, the average equatorial velocity V_0 seems greater than that reported by Rickett and Coles (1991) by ~ 70 km s^{-1}. This work was carried out in collaboration with Dr.V.Balasubramanian of RAC, Ooty and Prof.S.Ananthakrishnan of NCRA, Pune.

(P.Janardhan)

Latitudinal Variation of Electron Density Fluctuations

For studying latitudinal variation of elctron density fluctuations, ΔN_e, all sources with 100 mas $\leq \theta \leq$150 mas (1 mas = milli arcsecond) observed in the elongation (ε) range $13^\circ \leq \varepsilon \leq 25^\circ$, corresponding to distances of 50 to 92 solar radii from the sun, were selected. The results are presented in a polar plot of scintillation index m vs heliographic latitude γ with the sun at the origin (**Fig. 1.17**). As all observations were made east of the sun, we have an one-sided plot. Each of the plotted points, shown by filled circles, represents the average value of m over a 6° bin of γ. It is clear that the ΔN_e distribution deviates from spherical symmetry as one approaches the poles. The axial ratio of the best fit ellipse was found to be 1.24, while the reduction in ΔN_e at the poles was about 19% which implies reduction in the electron density towards the poles.

In a recent study it was shown that the ΔN_e distribution changed from being spherically symmetric at solar maximum to a distribution that was flattened towards the polar regions at solar minimum with a reduction of ΔN_e in the poles by a factor of ~ 2.5. The observed ΔN_e distribution that shows smaller departure from spherical symmetry and the velocity gradient suggests that the polar coronal hole regions have begun to expand equatorward. It will be very interesting to compare these results with those from the Ulysses satellite. This work was carried out in collaboration with Dr.V.Balasubramanian of RAC, Ooty and Prof. S.Ananthakrishnan of NCRA, Pune.

(P.Janardhan)

SOLAR PHYSICS (Udaipur Solar Observatory)

Electric Currents, Lorentz Forces and Magnetic Shear Evolution During Flares of M- and X-Class

Strong transverse fields, magnetic field gradient, electric currents, and magnetic shear are all usually found to be associated with locations where large flares are observed, and it is expected that these parameters should undergo some detectable changes at least during the course of major flares. However, previous studies

have reported a confusing variety of changes before, during and after some flares because of severe observational uncertainities.

We have studied a number of flares of M-, and X-class to look for changes in the magnetic field parameters, and to understand the mechanism of the magnetic energy storage and release. Change in shear was not found to be as impulsive as reported by some earlier studies even in major X-class flares, while, it was further less pronounced for M-class flares. In a superactive region, AR6555 that produced several X-class flares, vertical current-systems of the order of 10^{12} amperes were found to exist (**Fig. 1.18a**). Corresponding to these currents, substantial Lorentz forces were present at the photosphere, which opposed the observed sunspot motions at the polarity inversion (neutral) line — largest magnitude being about 2×10^{-3} N m^{-3} (**Fig. 1.18b**). Therefore, the Lorentz force may correspond to the pressure-driven horizontal plasma motions that produce magnetic free-energy storage. Another important result was the presence of a null-point at the upper chromosphere/lower coronal height, above the flaring location, corresponding to an X-class flare, where all the three components of the magnetic field vanished. This has important implication, as the plasma-beta near this null location would be near or above unity, and large electric currents may easily be produced by externally driven motions. (This work was carried out in collaboration with J. Fontenla, and M.J. Hagyard).

(A. Ambastha)

A Large Flare in an Area of Weak Magnetic Field and Low Magnetic Shear: A Counter-Example

A large flare of importance 4B/M7.3 occurred in an area of weak magnetic field and shear near active region NOAA 6853 on September 29, 1991/15:21UT. This particular event contradicts the general belief that large flares prefer to occur in locations of strong magnetic fields and large magnetic shear. Prior to the onset of the two-ribbon flare, destabilization and eventual eruption of an extensive, dark filament took place, which was perhaps triggered by the changes taking place in remote locations of sheared structures. The magnetic energy stored in the filament may have provided the energy released in the observed flare. A faint loop-like structure, visible in Hα , was observed to have one of its foot-points close to the filament in a sheared location. The other end of the loop connected into another sheared location in the opposite polarity area. We suggest that the interaction of this sheared loop with the magnetic fields supporting the large filament led to the filament destabilization. Significant changes in the orientation of transverse fields were seen near the filament-loop location during the course of the flare.

From more than 25 MSFC vector magnetograms taken before, during and after the flare, a clear decrease in an area-averaged shear index was found around the flare onset time computed over an area-of-interest near the flare-site (**Fig 1.19**). As compared to its preflare value of 45° the shear index decreased to 34° and as the flare evolved, it gradually but significantly increased to 50° much after the flare reached its maximum phase, and ultimately started decreasing. This feature contradicts the expectation that overall level of shear should decrease after a major flare. Implications of these results are being studied.

(A. Ambastha)

Soft X-ray Blow-outs and Coronal Holes

We have examined Yohkoh Soft X-ray Telescope (SXT) movies to look for events that could be related with coronal holes and other solar surface activity. We found that some soft X-ray ejections occurred in quiet regions and extended to more than half the solar radius. We call these events "X-ray Blow-outs" (XBOs) as they appear similar to streamer blow-outs in white-light coronal images.

Fifteen large-scale XBOs were detected in Yohkoh SXT movies during the period May 1992-December 1993. We made precise superposition of Yohkoh SXT Images, Stanford magnetic and coronal hole maps, and Hα full-disk filtergrams obtained from Udaipur Solar Observatory, India, and Solar Geophysical Data (SGD). All fifteen nonactive-region XBOs occurred near or at a coronal hole boundary and always developed over a

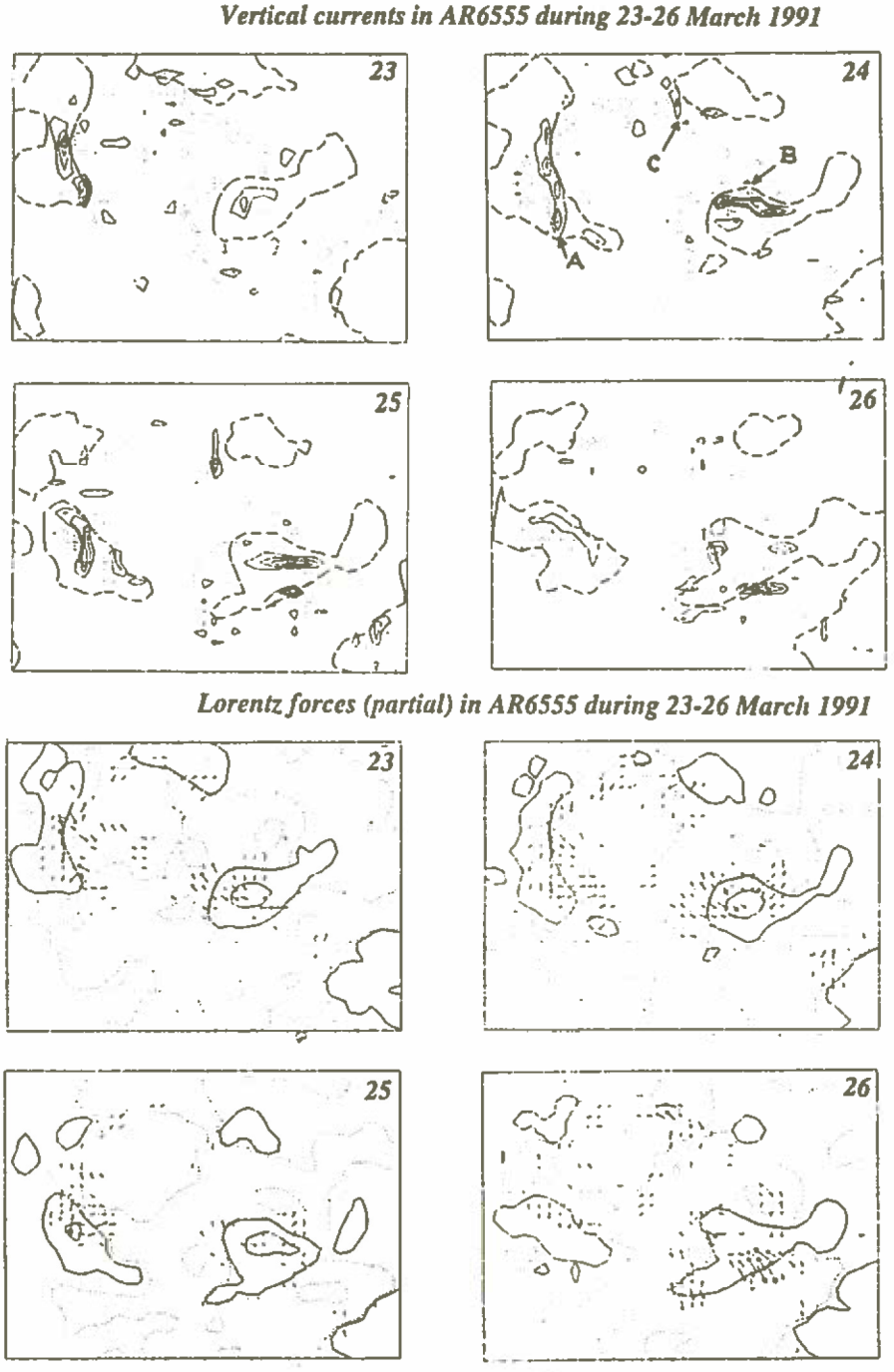


Fig. 1.18. Daily evolution of vertical currents and corresponding Lorentz forces in NOAA AR6555 during March 23-26, 1991. (a) Three locations of substantial currents, "A", "B", and "C" are marked, which were also the locations of enhanced activity in the active region. Heavy dashed lines represent polarity inversion lines, while solid (dotted) contours denote upflow (downflow) currents. The lowest current contour corresponds to ± 4 mA m^{-2}, separated by 8 mA m^{-2}. (b) The solid (dotted) contours correspond to line-of-sight magnetic field strengths of ± 100G, and ±1000G and the vectors denote the magnitude and orientation of Lorentz forces in the active region; maximum magnitude being of the order of 10^{-3} N m^{-3}.

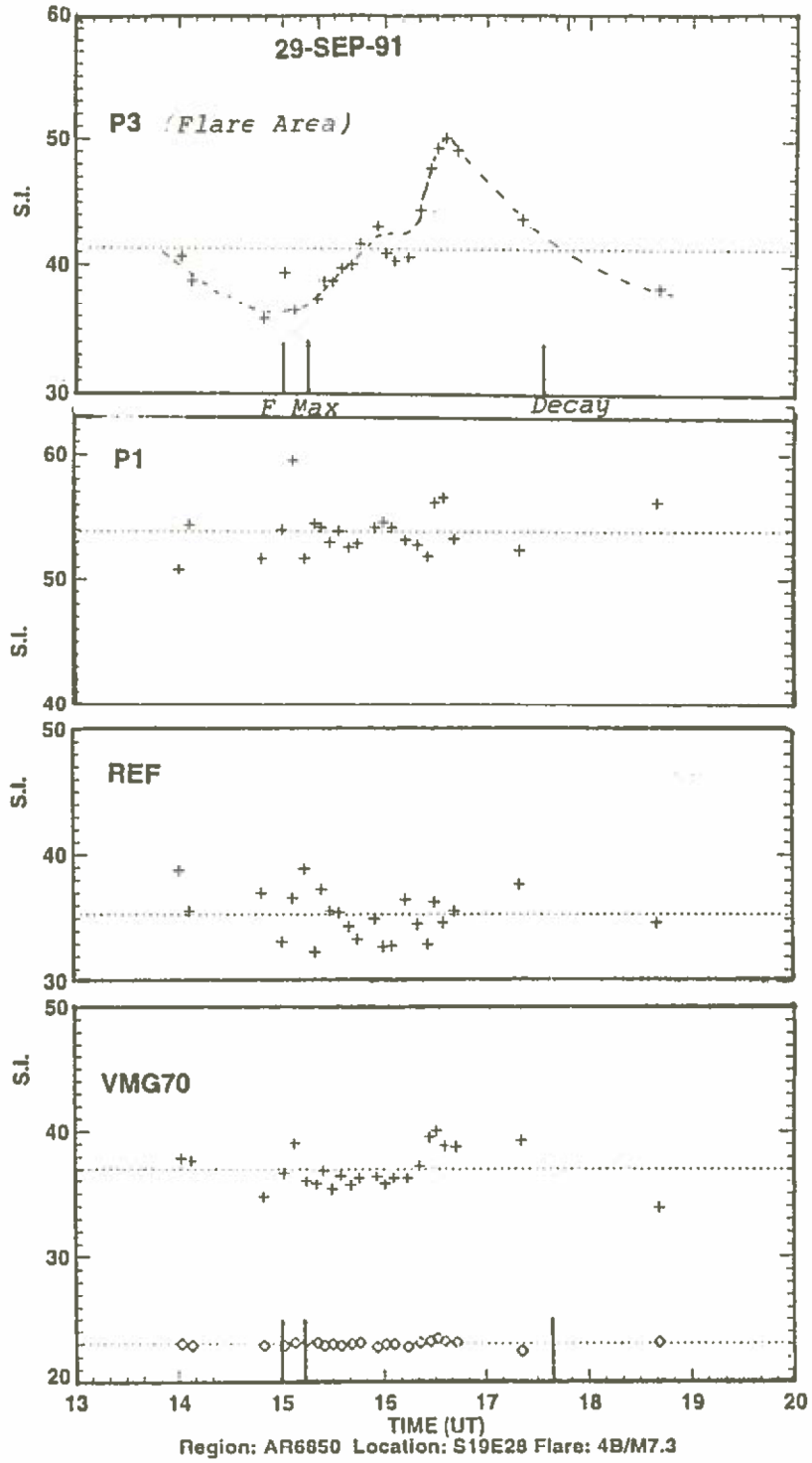


Fig. 1.19. Time-profiles of shear indices evaluated over 70x70 pixel area (VMG70), 15x15 pixel reference area (REF), and the subareas P1, P3 in AR6850 on September 29, 1991 during 14:50-18:40 UT. The onset, maximum phase and the decay time of the flare are marked at the bottom of the figures. While no definite trend is seen for the reference subarea REF, a decrease in shear index around the flare onset time is evident in P3, the subarea closest to the flare.

magnetic polarity inversion. No Hα features were associated with these events. We propose that the open magnetic field configuration of the coronal holes, adjacent to large-scale closed coronal structures, provides the necessary field geometry for magnetic reconnection to take place high in the corona. This results in high temperature soft X-ray emission visible as X-ray "blow-outs" apparently not affecting the features in or close to the chromosphere.

(A.Bhatnagar)

Energetic, Behind the Limb, Solar Flare of September 29,1989

A very energetic cosmic ray flare occurred on 29 September 1989, behind the limb and was observed over a wide spectral range. The analyses of optical, radio and other relevant data suggest two phases of energy release. After an impulsive phase, a prolonged post-eruption energy release occurred in an extended region of the corona, following the eruption of a large coronal mass ejection (CME). This phase was responsible for numerous coronal and interplanetary phenomena including the ground-level increase of cosmic rays. (This work was carried out in collaboration with J.T. Burkepile, I. Chertok, A.Magun, H. Urbarz and P. Zlobec).

(A. Bhatnagar and R.M. Jain)

Attempt to Detect Foot-points of Filaments

Observations were made at the Big Bear Solar Observatory, California of a filament in Hα , K-line and longitudinal magnetic field over a period of four days in June 1994 to detect the anchorage of the foot-points of the filament. Preliminary analysis of the data indicates that small fields of the order of 10-12 Gauss are cospatial with filament foot-points as indicated by K-line emission patches.

(A.Bhatnagar)

Longitudinal Magnetic Field Measurement on the Solar Photosphere using a Video Magnetograph (VMG)

At USO, we have recently made operational a Video Magnetograph on 25cm aperture Spar telescope to measure the longitudinal (line-of-sight) component of solar magnetic field using the principle of Zeeman effect. For this purpose we have used a solid state, voltage tunable Lithium Niobate Fabry-Perot etalon, having a passband of 170 mA as the filter to limit the light to one of the wings of photospheric CaI 6122A absorption line. This line is magnetically sensitive, having a Landè factor g = 2.0. To obtain the longitudinal magnetic field, it is required to analyze the state of circular polarization of the Zeeman components. In order to achieve this goal, a KD*P electro-optic crystal is used to alternately allow one of the circularly polarized component at a time. A large number of digital images, of the order of 128 to 256, are averaged for both the circular polarizations and then subtracted on-line, and at real-time, to produce a video magnetogram. The resultant intensity is proportional to the separation of the circularly polarized component and thus proportional to the magnetic field strength. Almost simultaneous images are also made in chromospheric layer in Hα 6563 A by using the same Fabry-Perot etalon filter. The data acquisition system consists of a COHU CCD camera with 699x576 pixels and a real-time image acquisition system IDAS. The field of view is 127"x95" on the sun.

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

Chromospheric, Photospheric, Magnetic Field Evolution and the Flare Activity of Super Active Region NOAA 6555

The super active region NOAA 6555 was highly flare-productive during its disk passage between 21 to 27 March 1991. We have studied the chromospheric activities of this superactive region by using high spatial resolution Hα filtergrams obtained at USO along with vector magnetograms obtained from MSFC and photoheliograms from Debrecen and IIA (**Fig. 1.20**). It is found that more energetic flaring activity occurred during the phase when the average area per sunspot in the active region was declining. Its subareas having both a high magnetic shear and large sunspot motion were found to be more active. Hα flare-ribbons occurred in the vicinity of, and not over the high shear areas. Flares

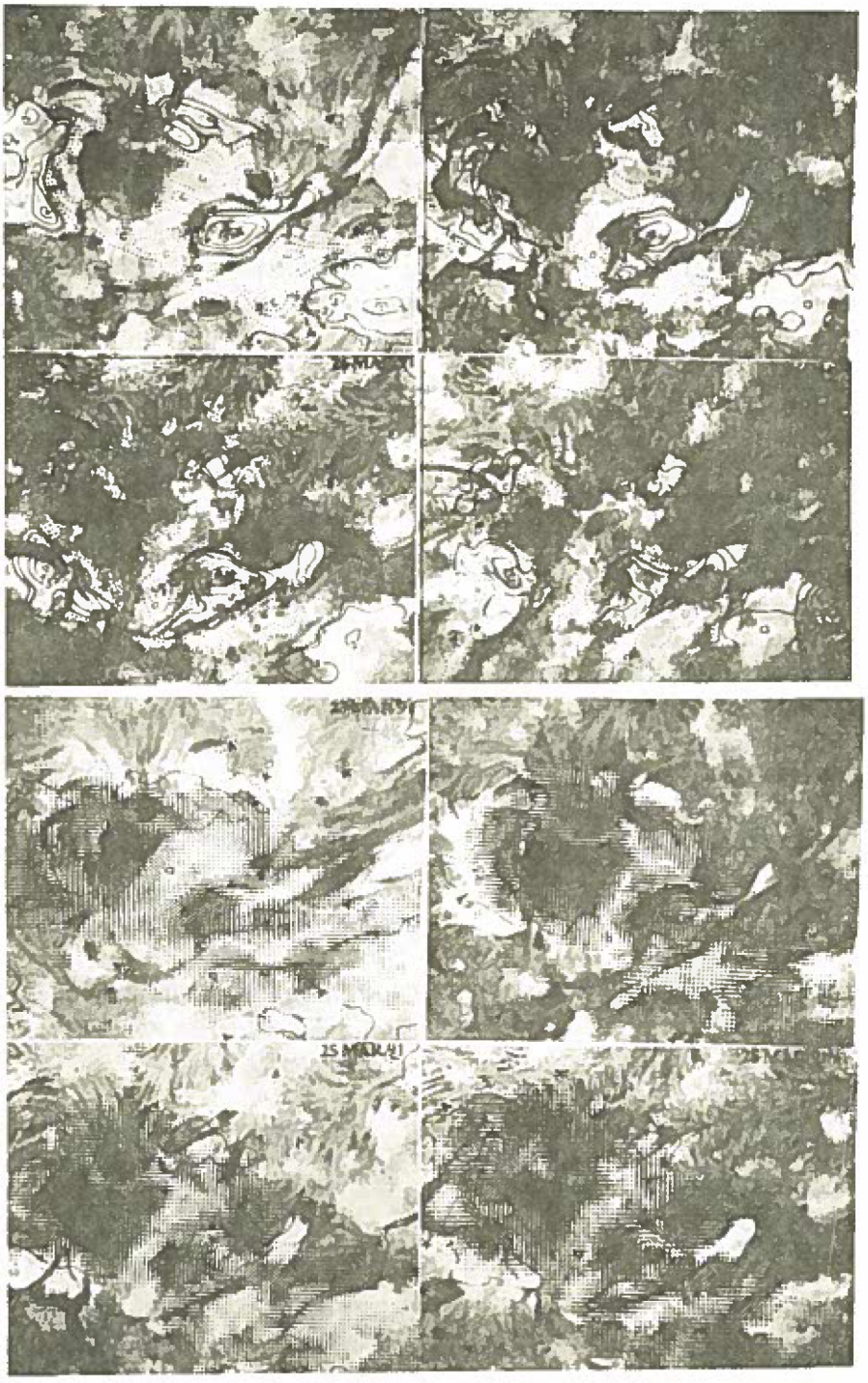


Fig. 1.20. Overlays of H-alpha filtergrams (USO) and MSFC magnetograms showing the daily evolution of chromospheric structures and magnetic fields in AR6555. The top panel shows contours of longitudinal fields corresponding to ± 10, ± 100, ± 500, ± 1000, ± 1500 G, while the bottom panel displays the line-segments corresponding to the transverse field.

generally occurred in those subareas that possessed closed magnetic field configuration, whereas only subflares or surges were observed in subareas having open magnetic field configuration. This work has been done in collaboration with Mona J. Hagyard of Marshall Space Fight Centre, USA.

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

Photospheric and Chromospheric Activity Associated with a 3B Flare of February 27, 1992

We have analyzed the Hα filtergrams, photoheliograms, and vector magnetograms of the active region NOAA 7070 in which a 3B/X3.3 flare occurred on February 27, 1992. The average area per sunspot in this active region, was in declining phase at the time of the flare. This implies that the active region was highly dynamic and evolving, dominated by sunspot fragmentation. The vector magnetograms obtained from Okayama Observatory, Japan, and MSFC, USA, indicated that the magnetic field was highly sheared at the flaring site. Besides strong nonpotentiality, the gradient of the longitudinal field was found to be the highest at the region showing initial Hα brightening. Further, the Hα filtergrams showed that the morphology of the filament tracing the magnetic neutral line did not change significantly in the post-flare stage. Photospheric vector magnetograms showed that there was considerable shear left even in the post-flare magnetic field structure of the active region.

(Debi Prasad C. and Nandita Srivastava)

A Possible Explanation of Reversed Magnetic Field Features Observed in NOAA AR 7321

Observation of reversed polarity features in the chromosphere as well as in the photosphere in the form of magnetic gulfs or islands of opposite polarity have been reported recently. We have presented a possible explanation for the appearance of reversed-polarity features observed in chromospheric magnetograms of the NOAA AR 7321 obtained during October 25-27, 1992 from the Beijing Astronomical Observatory, Beijing. It is suggested that the large-scale reversed polarity features may occur due to the twisting of the small scale magnetic flux tubes in the layer between the photosphere and the chromosphere. Some of the observed facts, for example, high transverse magnetic field strengths, correlation with flare sites and blue-shifts associated with these reverse polarity structures have also been explained. This work was carried out in collaboration with Yang Liu, Wei Li and Guoxiang Ai of Beijing Astronomical Observatory, Beijing.

(Nandita Srivastava and Debi Prasad C.)

Three Dimensional Velocity Observations using Multi-slit Spectrograph

Multi-slit observations of active regions NOAA 7871, NOAA 7873 and NOAA 7874 which produced flares and also of prominences have been made in Hα line to obtain line-of-sight velocities. These spectra have been recorded using the Littrow spectrograph with a dispersion of 6 A mm^{-1} and a spectral resolution of 0.13 A on a digital format by a CCD camera. Digital slit-jaw images have also been recorded simultaneously using a 0.5 A passband Daystar Hα filter and a CCD camera.

(Nandita Srivastava and Arvind Bhatnagar)

Sensitivity of the Solar Neutrino Flux to Opacity Changes

The sensitivity of the solar neutrino fluxes to localized opacity changes is investigated by constructing static and evolution models of the sun. We find that an increase of the opacity in the temperature interval $7.06 < \log T < 6.94$ leads to an increase of the central opacity and hence central temperature (**Fig. 1.21**). As the generation of the high energy neutrinos are strongly coupled to the central temperature, a decrease in the neutrino flux is observed in the same temperature interval, the maximum reduction being 0.27% for an opacity change of roughly 5%, and 1.9% for an opacity change of 58%. Further, we have evaluated the neutrino flux kernels related to the opacity changes. We also show that the effect of even quite large opacity changes can be produced with substantial accuracy by simple linear relations involving

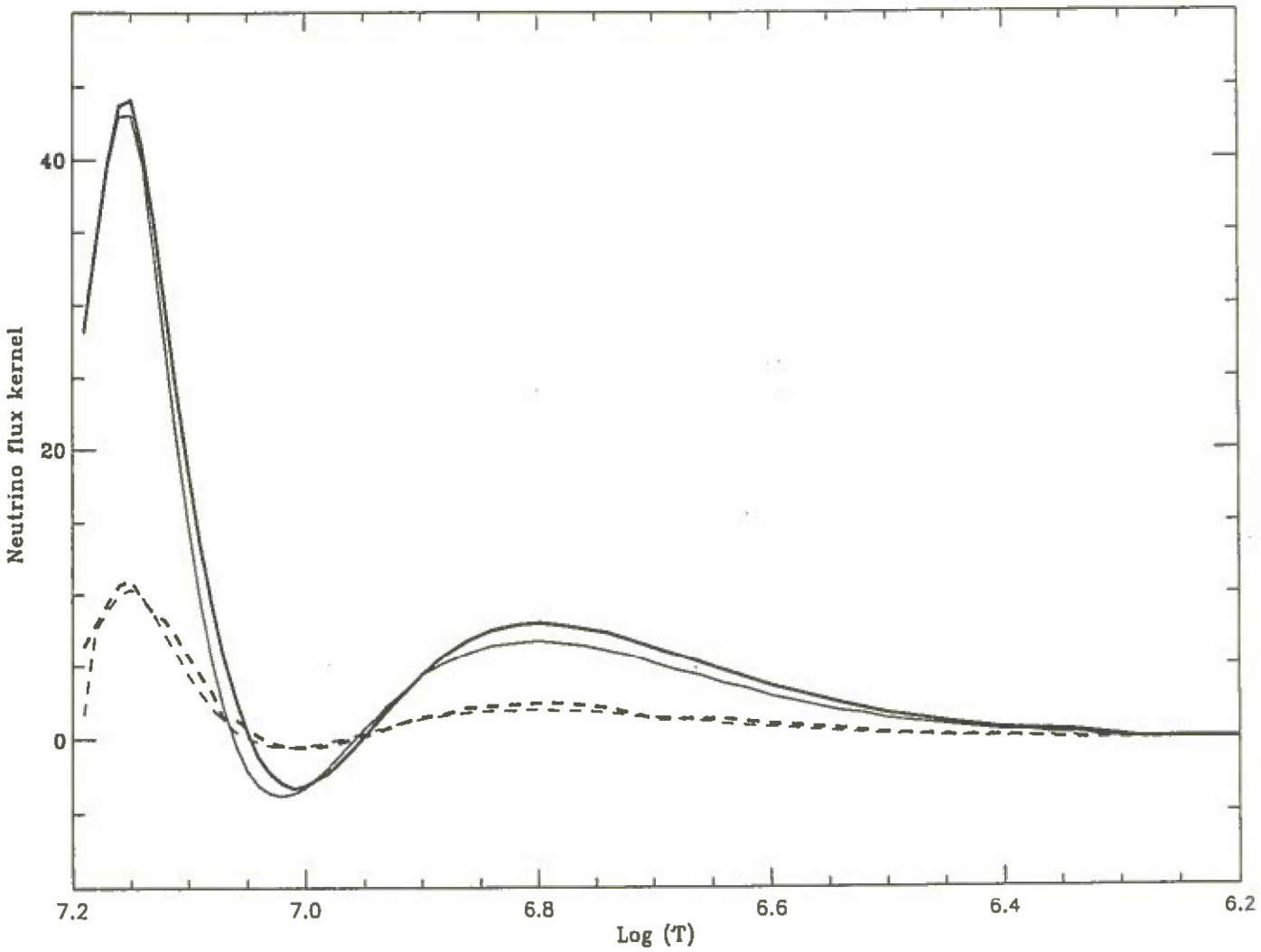


Fig. 1.21. Examples of kernels for Chlorine (37Cl) (solid) and Galiumè(71Ga) (dash-dot) neutrino flux for static (solid) and evolution models (dash-dot line) as a function of temperature. It is seen that the neutrino flux decreases in a particular interval even though the opacity is enhanced in that range.

suitable kernels. This work was carried out in collaboration with J. Christensen-Dalsgaard.

(S.C.Tripathy)

Detection of Chromospheric Oscillation in High-l Data

A ring diagram technique was used to search for 3-minute chromospheric oscillations in NSO high *l* Helioseismometer data. A variety of regions were studied, ranging in size from over 1 solar radius in diameter to supergranulation regions as delineated by the Ca K network. While the 5-minute oscillation was clearly seen in all analyzed regions, the predicted signature of the 3-minute chromospheric mode was not clearly detected in the power spectrum. The average spectrum from 16 areas of 50 x 50 arc-sec and all values of *l* was fitted with periodic and non-periodic components. The parameters of these fits roughly agree with earlier measurements from South Pole data providing further evidence of the chromospheric mode in the background. This work was carried out in collaboration with Frank Hill.

(S.C. Tripathy)

Nonlinear Shock Wave Propagation of NILF Mode in a Weakly Ionized Magnetoplasma

We have analytically investigated the formation of Neutral Induced Low Frequency (NILF) mode inducing weak nonlinear shock structure in a weakly ionized magnetoplasma. Using the reduction perturbation method, the basic dynamical equations of a three component plasma (electrons, ions and neutrals) has been reduced to a well known Burger's equation which supports weak shock solution. We have also derived stationary and initial value solutions which describe the characteristics of the weak shock profile. Asymptotic behaviour of the Burger's solution demonstrates a saw-tooth structure which could predict the nonlinear steepened structure of the night-time irregularity in lower portion of the earth's ionosphere. Accordingly, we suggest that the observation of saw-tooth shape of the night time irregularity at 92 km could be attributed to the nonlinear saturation of the NILF mode instability.

(C.B. Dwivedi and S.C. Tripathy)

BASIC PHYSICS LABORATORY

Observation of Discrete Energy States in a Classical Mechanical Domain.

We have new results in the experiments on the observation of existence of discrete energy states in the classical mechanical domain of parameters. The electron gun injects an electron beam parallel to a longitudinal magnetic field into a glass vacuum chamber, 85 cms in length and 11cms in diameter, evacuated to $5x10^{-7}$ torr. The experiment is carried out by sweeping the cathode voltage and measuring the detector plate current, the current flowing to the ground from a grid placed in front of the plate and the current through the anode. As reported earlier the plate and grid currents (profiles a,b in **Fig. 1.22**), instead of exhibiting a monotonically increasing behaviour, exhibit distinct dips at a series of energy values which were found to fit a relation obtained from a quantum-like theory predicting such a behaviour. Since these two currents are found to be anticorrelated, we have added the two currents to see if any modulation survives in the sum current and we still see a significant modulation (profile f) though as not large in the two individual profiles.

Next to see whether the actual position of the grid between the plate and the gun plays any particular role we have recorded the plate and grid currents (profiles d and e respectively) when the grid is positioned 10 cms away from the gun while the plate is left at 50 cms. Though the grid current is no longer anticorrelated with the plate current as in the set (a) and (b) the interpeak distances in the two plate current plots (a) and (d) are almost same and are determined by the distance between the gun and the plate, the change of the position of the grid has not significantly affected it. If we look at the grid current plot closely it is seen to exhibit variation on a small scale superposed over a large scale variation, while the plate current exhibits variation only on the small scale. It is seen that the small scale variation of the grid current is anticorrelated with the corresponding plate current profile both of which are characterised by the plate-gun distance (the inter-peak distance being inversely proportional to the distance). The large scale variation of the grid current, on the other hand, is found to be determined by the grid-gun distance (10 cm in the present case). The current profiles (c) and (g) represent anode currents in the two cases when the plate and grid currents are separately recorded and when they are joined respectively. It is seen that the two anode currents are almost the same and unaffected by combining the grid and plate.

The present set of experiments have thus conclusively shown that the observed peaks in plate current profiles could not be due to any physical obstruction by the grid and that they are not governed by the position of the grid. The large scale patterns observed in the grid current profiles has raised many interesting questions and experiments are being continued to answer them.

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

Dusty Plasma Experiment

Experiments have been done to study the interaction between a steady state flowing plasma and dust with a view to investigate the charecteristics of dust charging. The plasma, produced with the help of a PIG type gun,

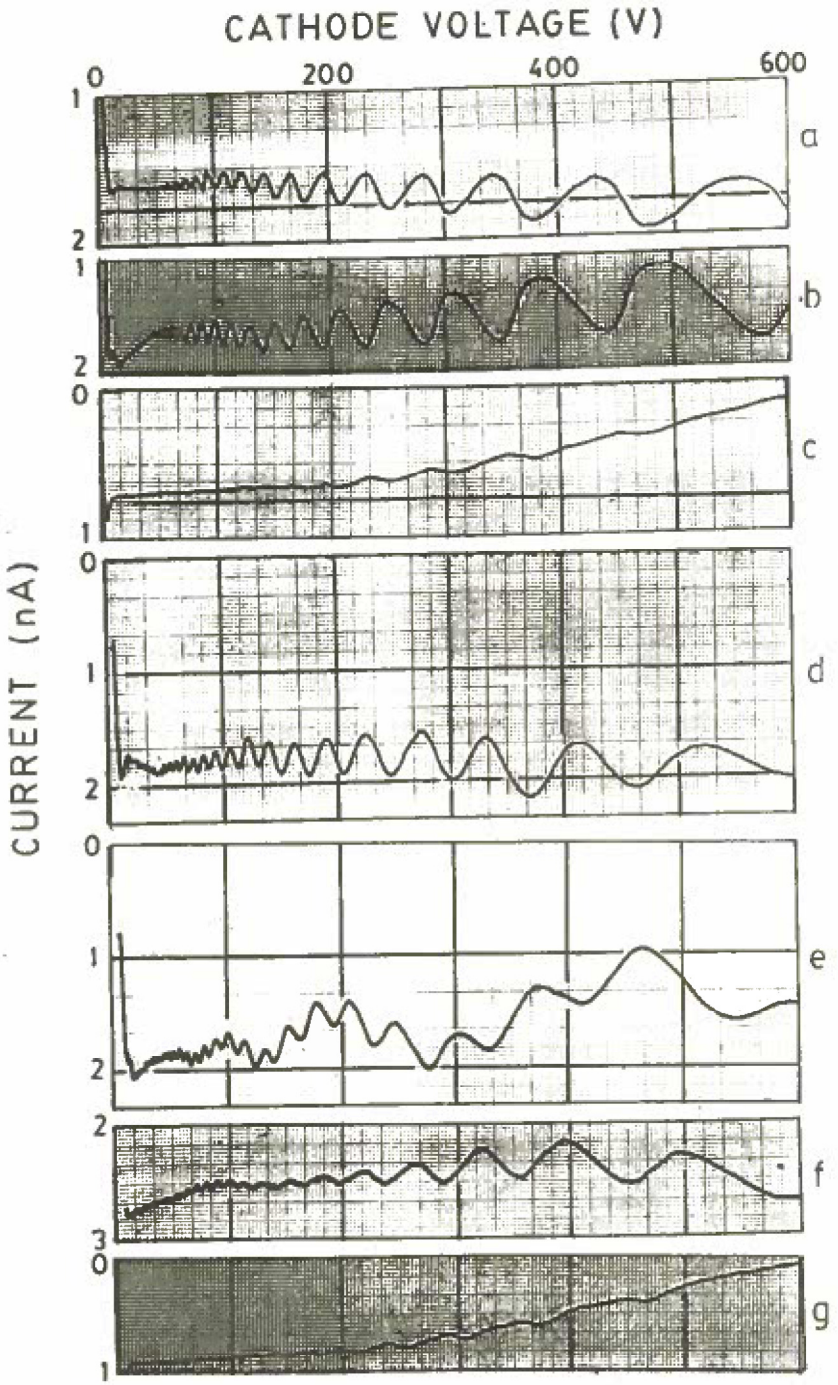


Fig. 1.22 Current profiles as function of the cathode voltage: a and b are the plate and grid currents recorded separately when the plate and grid are 50cms and 48.5 cms away from the gun; d and e are the plate and grid currents recorded separately when the plate and grid are 50cms and 10 cms away from the gun; f is the current profile when the plate and grid are shorted; c and g represent anode currents in the two cases when the plate and grid currents are recorded separately and when they are joined.

flows into a glass chamber 50 cms long and 10 cms in diameter, evacuated to $5x10^{-6}$ torr., placed in an axial magnetic field around 50 G. The Aluminium Oxide dust with 30 microns as the upper limit of particle size is injected into the plasma in a pulsed mode from a duster. The average particle size is about 10 microns and approximately 10,000 particles are injected in one pulse. Plasma parameters obtained with the help of a movable probe show that the plasma density is $3x10^{10}$ per c.c. For estimating the average value of Q/m, the mass of the dust injected during 50 shots was measured and the Q/m value thus obtained in the preliminary experiments is $18x10^{-3}$ Coulomb/gram for each pulse, The main observations are as under:

i. During the pulsed injection of the dust, the current signal recorded by a plate, placed right below the duster shows a negative peak, indicating that the dust is negatively charged and the number of electrons associated with it is ~ $1.5x10^{12}$.

ii. The ion current collected by the Langmuir probe shows an increase in the presence of the dust indicating loss of electrons to the dust particles.

iii. Though the dust injection is localised the changes in the probe characteristics caused by the dust injection is observed over long distances from the point of injection (6 cms towards the gun side and 4 cms towards the analyser side). This is further corroborated by the currents measured by an array of detector plates placed along the length of the glass chamber.

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

Particle Confinement in Magnetic Mirrors

An experimental device is being set up to study the confinement of charged particles in a mirror magnetic field. There are several approaches theoretically interpreting the leakage of charged particles from an adiabatic mirror. The predictions arising out of the theory developed by one of the authors has been the subject matter of verification in a number of experiments carried out in PRL. In our present experiment we intend to study particle capture and loss processes in a multiple mirror system. The system would consist of a central mirror , supplemented at each end by a number of smaller volume mirror cells for the purpose of plugging the end losses. The experiments will be aimed at verifying predictions which show that when the end cells are made asymmetric, the probability of the end losses in a particular direction i.e., towards the central cell gets enhanced and hence the efficiency of particle capture in the system as a whole, could be increased as compared to the case, with symmetric cells. We intend to experimentally study the role of asymmetry in the magnetic field configuration of the end cells.

Prior to carrying out the above mentioned experiment, we plan to study the particle confinement in mirror configurations with different widths of the magnetic field peaks maintaining the scale length and the height of the peaks constant. An experimental set up has been designed and developed. An electron gun capable of producing a beam within an energy range 600eV-5keV and any desired pitch angle is mounted at the end of an S.S. chamber 27 cms in diameter and 3.1m long. The gun is placed outside mirror magnetic field and a 50 ns high voltage positive pulse, applied to a cylindrical electrode placed underneath the peak magnetic field facilitates the entry of electrons into the mirror field. A system of magnetic coils fed by two high current power supplies produces the required configurations of the magnetic field. The work has been completed on the pulse forming network, producing 50 ns pulses and the magnetic field configurations with different widths of one of the mirrors maintaining the mirror ratio constant. Preliminary results on device are expected in the next few months.

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

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

UPPER ATMOSPHERE

Characteristics of Plasma Bubbles on the Topside of the Ionosphere

An investigation was carried out by means of the nonlinear numerical simulation model of equatorial spread-F (ESF) developed in PRL to understand the characteristics of the plasma bubbles with different topside ionosphere as the background conditions. For this investigation, two electron density profiles with the same bottom sides and with different slopes on the top sides are used as basic inputs to the model. The investigation revealed that the zonal and vertical extents of the plasma bubbles and their upward drifts depend significantly on the plasma density gradient on the topside of the ionosphere. The bubble associated with lesser plasma density gradient on the topside elongates in the vertical direction with limited zonal extent, while the bubble associated with steeper gradient mushrooms in zonal direction (**Fig. 2.1**). The buoyancy movement of the bubble associated with lesser plasma density gradient is larger which in turn affects the size and shape of the plasma bubble. Thus the recently reported observational differences in the size and vertical velocity of the plasma bubbles over Kwajalein (9.4° N, 167.5° E)in comparison to the observations reported over

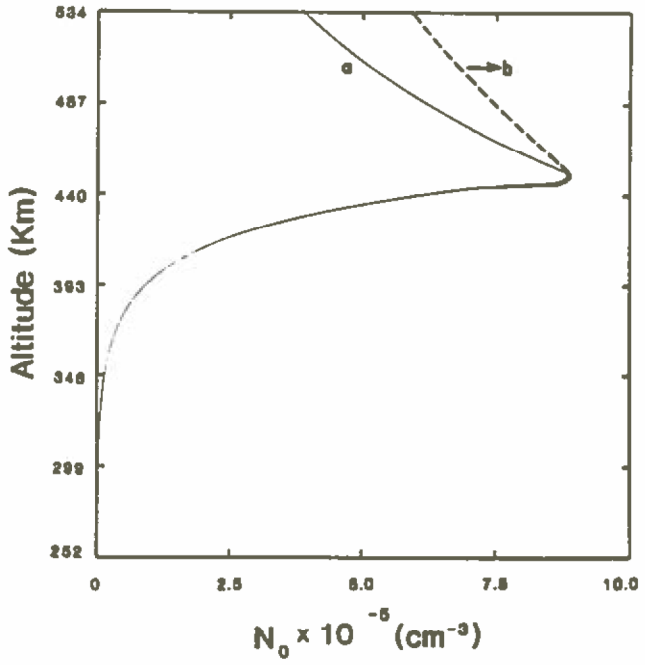


Fig. 2.1A The input electron density profile with two different topside electron density gradients, for nonlinear numerical simulation model.

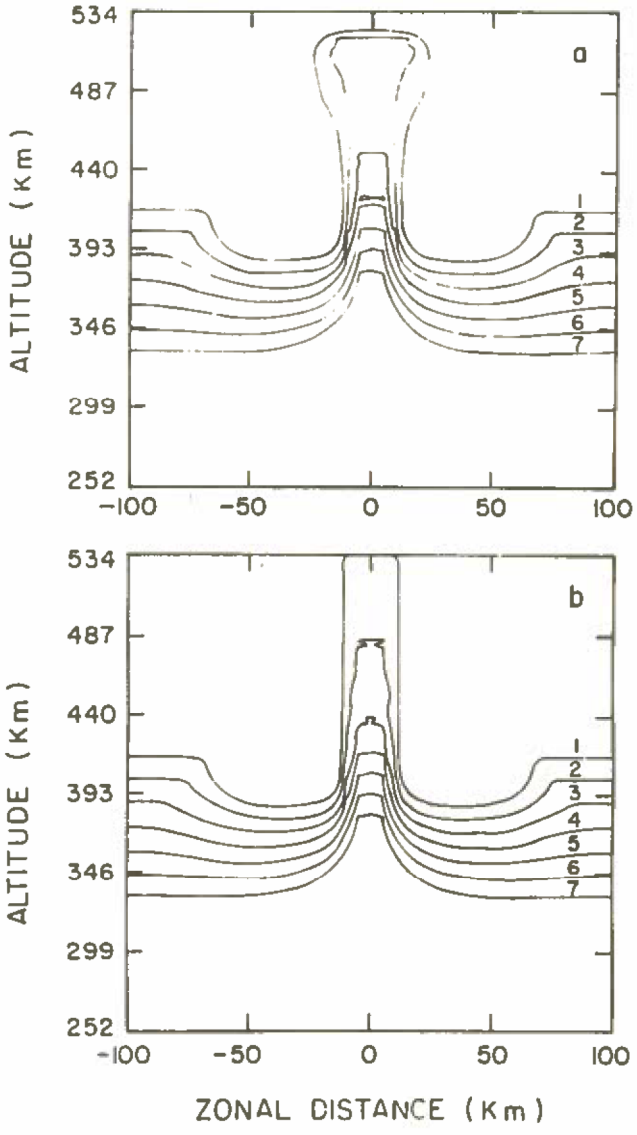


Fig. 2.1B (Top) The evolution of the plasma bubble associated with the steeper plasma density gradient on the topside (Case a). (Bottom) Same as above for Case b with lesser plasma density gradient on the topside.

Jicamarca (11.96° S, 76.9° W) are explained on the basis of the typically observed plasma density gradients in the topsides of those regimes. This work was done in collaboration with Prof. R.Raghavarao.

(R. Sekar)

Results from 'Ionization-hole' Experiment

Results from in situ RH-560 rocket experiments for the investigation of the processes associated with the formation of an 'ionization-hole' in the evening/nighttime equatorial F-region and the role of neutral dynamics in the formation of the 'hole' have become available after a detailed analysis. The preliminary results were reported last year. The vapour cloud release experiment reveals significant magnitude of eastward wind (120 ms^{-1}) around 300 km and strong shear (1.5 x 10^{-3} s^{-1}) in the meridional wind profile centered around 250 km altitude (**Fig. 2.2**). Significant magnitudes of vertical wind (~ 20 ms^{-1}) were also present with downward polarity around 200 km and upward polarity in the lower height regions. The zonal and meridional wind patterns appear to corroborate the modified wind system as expected by the newly discovered phenomena of equatorial temperature and wind anomaly (ETWA) and its associated processes.

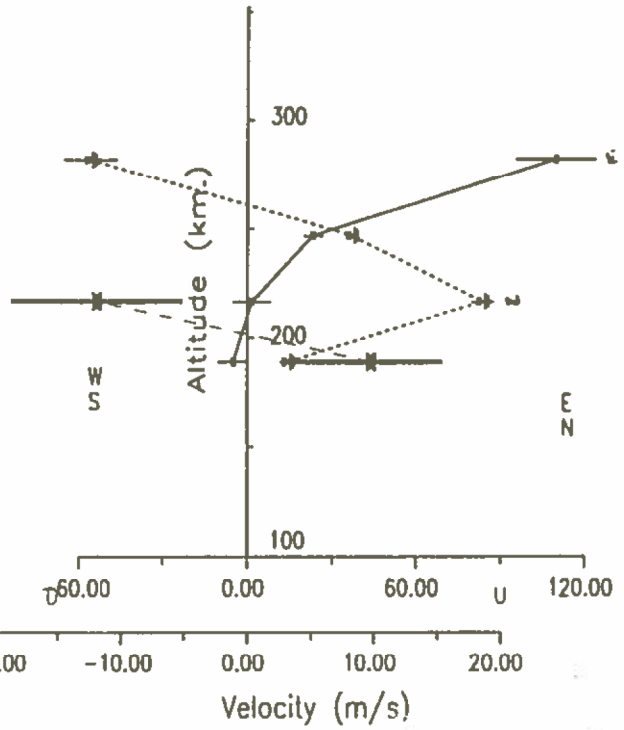


Fig. 2.2 Altitude profiles of the three wind components viz., zonal wind, meridional wind and vertical wind on February 19, 1993 as obtained from high altitude RH-560 Ba-vapour releases from SHAR.

Detailed analysis of the Indo-Soviet mass spectrometer data reveal that the molecular ions NO^+ and O_2^+ are dominant upto the apogee of the rocket, while O^+, the otherwise dominant ion during daytime as well as later in the nighttime, formed only 30%. These are due to the electrodynamical effects associated with the post sunset enhancement of the east-west electric fields over the equator. Large scale irregular structures in the ion density profiles are present in the altitude region of 200 - 300 km, confirming our earlier rocket measurements. The molecular ions O_2^+ and NO^+ show complementary behaviour while O^+ ion varies similar to NO^+, contrary to the results from earlier satellite experiments (**Fig. 2.3**). The location of the irregular structures in a region of less plasma density gradient calls for a different mechanism other than the Rayleigh-Taylor instability, operating in cascade with the latter, in order to explain their formation and evolution into an ionization hole.

These results would form as inputs to the nonlinear numerical simulation model for further detailed analysis to bring out the relative importance of various destabilising agencies.

(R. Sridharan, R. Sekar, R. Narayanan, S.R. Das, N. K. Modi and C.L. Piplapure)

Evolution of the Equatorial Ionization Anomaly (EIA) as Monitored by OI 630.0 nm Dayglow Measurements

The OI 630.0 nm dayglow intensities have earlier been shown by us to depend significantly on the F-region electron densities and the variation in it. Using this factual information a precursor for the enigmatic nighttime phenomenon of equatorial spread-F was obtained and reported last year. Bidirectional switching mode operation of the photometer from Waltair provided clues on the strength of EIA, which was later used in deriving a

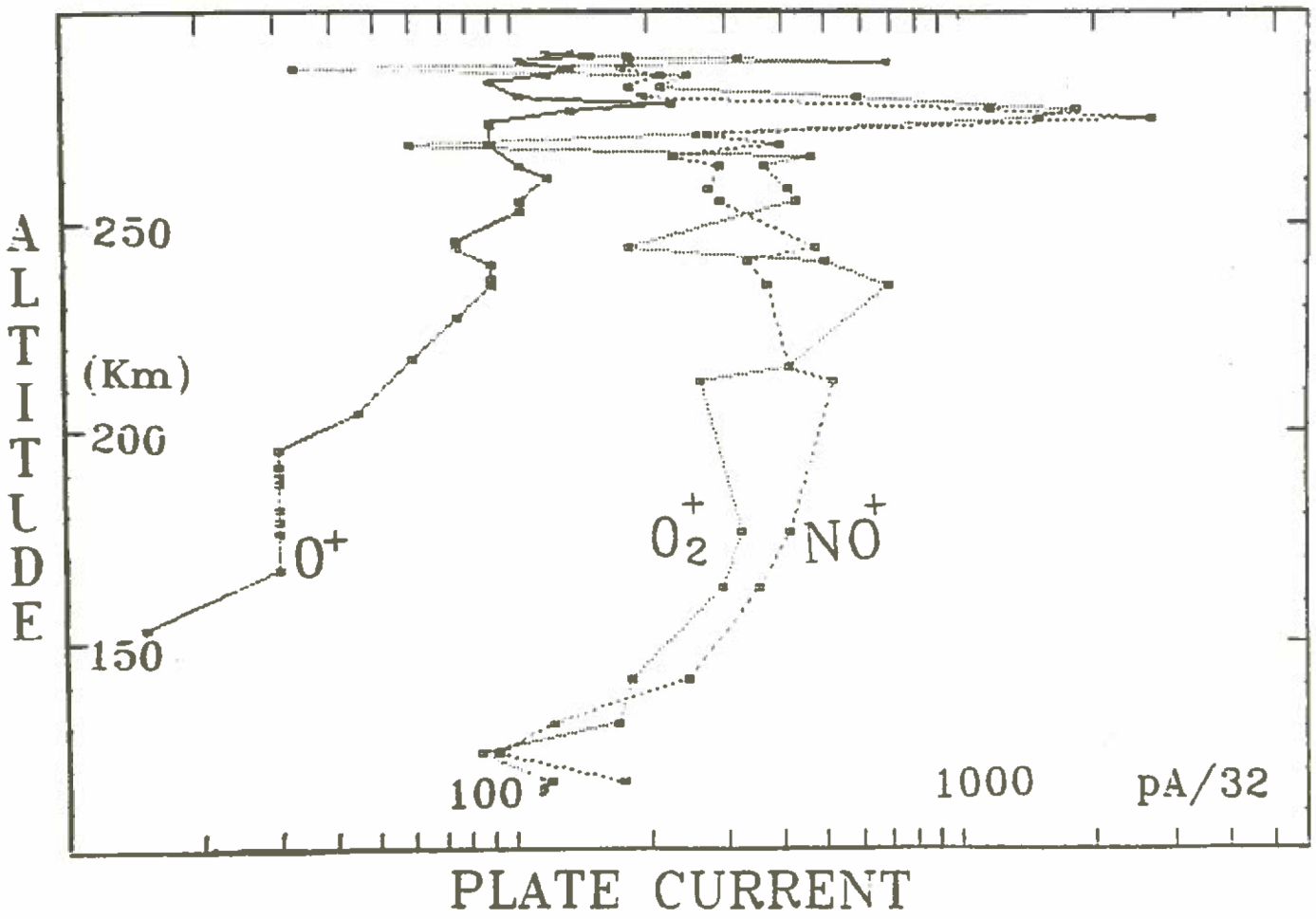


Fig. 2.3 Altitude profiles of ion densities during the ionization-hole experiment. Large scale irregular structures are seen above 200 km well below the base of the F-region. The dominance of molecular ions NO^+ , and O_2^+ and their complementary behaviour are to be noted.

precursor atleast 3hrs. prior to its actual occurrence as seen by ground based ionosondes. The dayglow photometer was operated in a meridional scanning mode from Ahmedabad pointing south and the gradients in the excess dayglow intensity and its variation with time provided the first evolutionary pattern of EIA with unprecedented spatial and temporal resolution by means of ground based optical technique (**Fig. 2.4**). These results were confirmed from the strength of the primary electric field over the dip equator as inferred from the ground based magnetometric measurements of the strength of the equatorial electrojet. The evolutionary pattern of EIA from OI 630.0 nm dayglow showed significant similarities with the representative TEC measurements on EIA during a similar epoch. The present results provide newer insight into the global scale dynamo action that manifests as primary east-west electric field over the dip equator. This work was done in collaboration with Prof. R. Raghavarao.

(D. Pallam Raju and R. Sridharan)

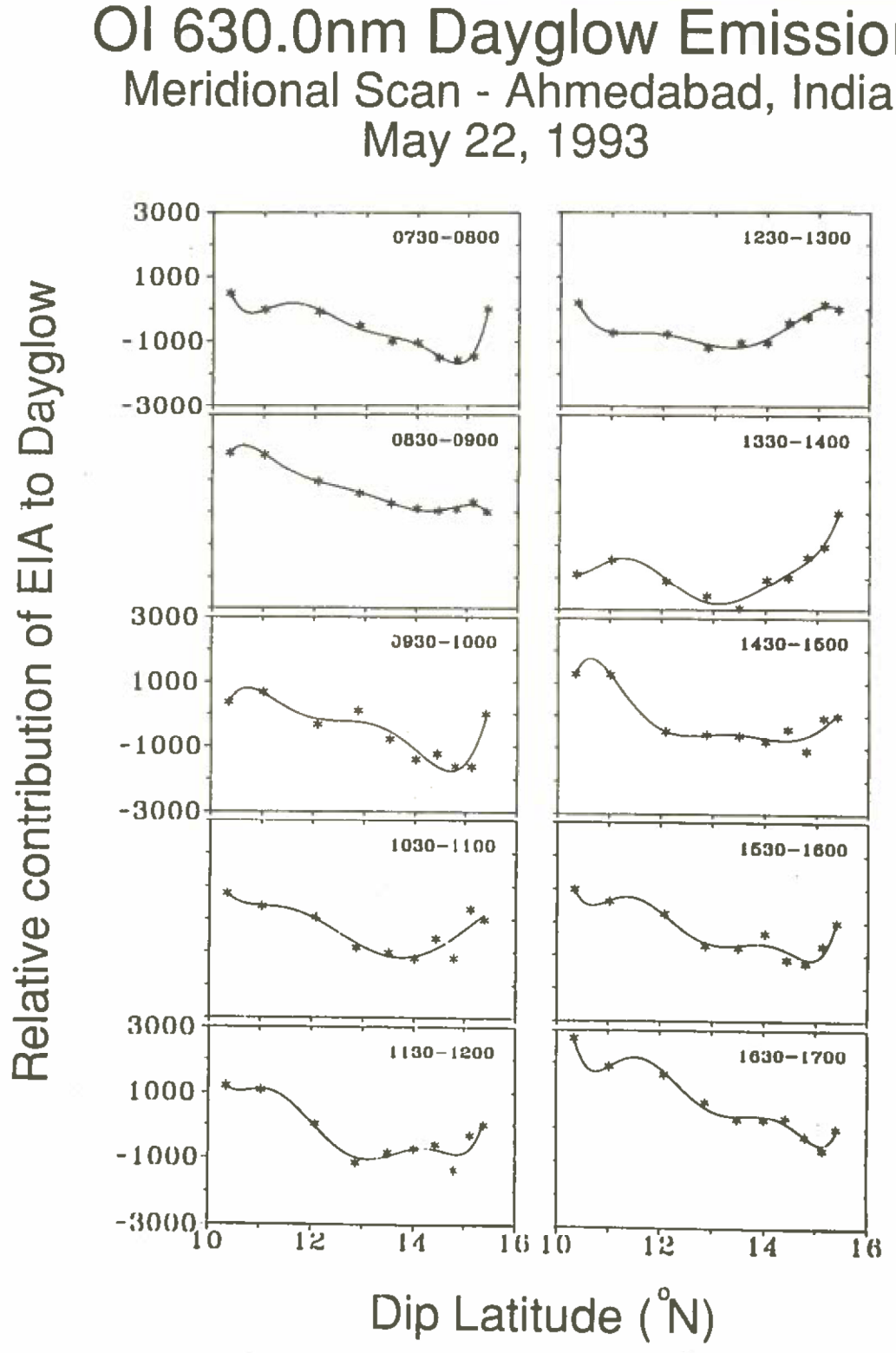


Fig. 2.4 Hourly plots of EIA contribution to dayglow at different dip latitudes on May 22, 1993, providing the evolutionary pattern of EIA.

Behaviour of the Low Latitude Thermosphere-Ionosphere System (TIS) during a Geomagnetic Storm

The thermosphere and the F-region of the ionosphere have been proven to behave as a closely coupled system during magnetically quiet periods, by means of systematic coordinated measurements of the thermospheric temperatures and winds along with ionospheric measurements. Further studies are being carried out to find whether this servo system behaviour persists even during geomagnetically disturbed periods and to see whether any threshold exists beyond which the coupling breaks. A case study was performed during a moderate geomagnetic storm when simultaneous data on neutral temperature, meridional winds as well as F-region parameters were available. It is seen unambiguously that the coupling of the TIS is intact during this event. Further studies on the energetics during the geomagnetic storm pertaining to our latitudes revealed an interesting and new result. An estimate of the integrated energy input into the atmosphere as inferred from the Dst values, which are a measure of the energy input/release from the equatorial ring current showed one to one correlation with the meridional winds and also with the neutral temperature with a time delay of ~ 3 hrs. This is a clear indication for direct deposition of energy in the low latitude belt presumably from the ring current. This is apart from what would be transported from high latitudes by means of winds and waves. The latter would be felt typically after a time delay ranging from 7 - > 24 hrs. The present results confirm our earlier finding from a rocket experiment from SHAR during the initial phase of a geomagnetic storm. Detailed analysis is under progress.

(T. K. Pant, R. Sridharan and S. Gurubaran)

Study of Ionization Layers in the Nighttime E region by MST Radar

In-situ electron density measurements over SHAR during evening and nighttimes have shown the presence of layered structure in the 90-150 km region. One could clearly see two to three layers wherein the electron density varies by an order of magnitude in a vertical extent of five to ten kilometers. Similar sharp layers of ionization were also observed over an equatorial station Thumba during daytime in periods of counter electrojet and were explained in terms of compression of metallic ions by gravity wave winds.

In view of the importance of gravity waves present in the E-region, in producing sharp layers in the E-region and also their role in triggering the equatorial spread-F, an experiment was conducted to study the gravity waves using the Indian MST radar.

The MST radar was operated on seven nights during 11-18 May 1994. The altitude region of 85 to 150 km was studied with a range resolution of 0.6 km. Power spectral data recorded by the radar was used to determine the spectral moments and generate the range-time intensity diagrams. There were many occasions when more than one layer was present. An important feature about these layers, which has been observed for the first time in the Indian region, is that they have life times less than about a minute. Presently efforts are underway to determine vertical scale sizes, time periods and phase velocity of the gravity waves associated with these structures.

Coordinated ionosonde observations were also made at SHAR for all the seven nights. Association of E-region wave-like structure with the equatorial spread-F is being studied using the MST radar and SHAR ionograms.

(H.S.S. Sinha, P.K. Dwivedi, Shikha Raizada and H. Chandra)

Electron Densities in the Equatorial Lower Ionosphere over Thumba and SHAR for the International Reference Ionosphere (IRI)

The electron density data of 33 rocket flights conducted from India was studied to identify the major features which any reference ionospheric model such as IRI should be able to reproduce. The structure of the electron density profiles and the associated irregularities upto about 150 km over Thumba, India (8° 52 N, 76° 87 E, dip 0° 47 S) and upto about 340 km over SHAR, India

(13° 42 N, 80° E, dip 14° N) were studied. These profiles were obtained using rocket-borne Langmuir probes and resonance probes. In all, profiles of 27 rocket flights conducted from Thumba and 6 from SHAR were studied.

During the daytime normal electrojet (NEJ), the electron density profiles over Thumba were very smooth (**Fig. 2.5**) with only positive electron density gradients (i.e. the density increasing with increasing altitude). The rate of increase in the density above 100 km altitude was much slower as compared to below 100 km. During daytime counter electrojet (CEJ), sharp layers of electron density, having a vertical extent of a few km, ~ 100 km, were observed over Thumba. The nighttime profiles over Thumba (**Fig. 2.6**) show pronounced structures in the form of layers which are believed to be due to shears in the gravity wave winds. Morning and evening profiles over Thumba (around the twilight periods) show structures similar to the nighttime except that the peak densities are slightly smaller as compared to the nighttime values. The single daytime electron density profile available over SHAR during the NEJ period, shows the presence of a sharp layer around 90 km. Morning, evening and nighttime profiles over SHAR (**Fig. 2.7**) show a lot more structures as compared to the profiles over Thumba. These structures are believed to be due to the gravity waves. This work was done in collaboration with Prof. Satya Prakash.

(H.S.S. Sinha)

Characteristic Features of Stratifications in the E-region

Data of E region irregularities over Thumba were subjected to spectral analysis. During day time we observed irregularities in scale size 1-400 m which are due to electrojet current and cross field instability. We rarely see 1 km size structures, except during counter electrojet. But during night time we see thin layers of ionization in scale size 1 km to 10 km. In addition, we see small scale irregularities (1-100 m) as well. We did spectral analysis of night time irregularities in scale size 1 meter to 10 km. We found the spectral index to be about - 2.5. Since this value is close to the theoretical prediction (- 3.0), it indicates that the night time irregularities in the scale size of interest in E region over Thumba are potentially due to gravity waves.

(S.P. Gupta)

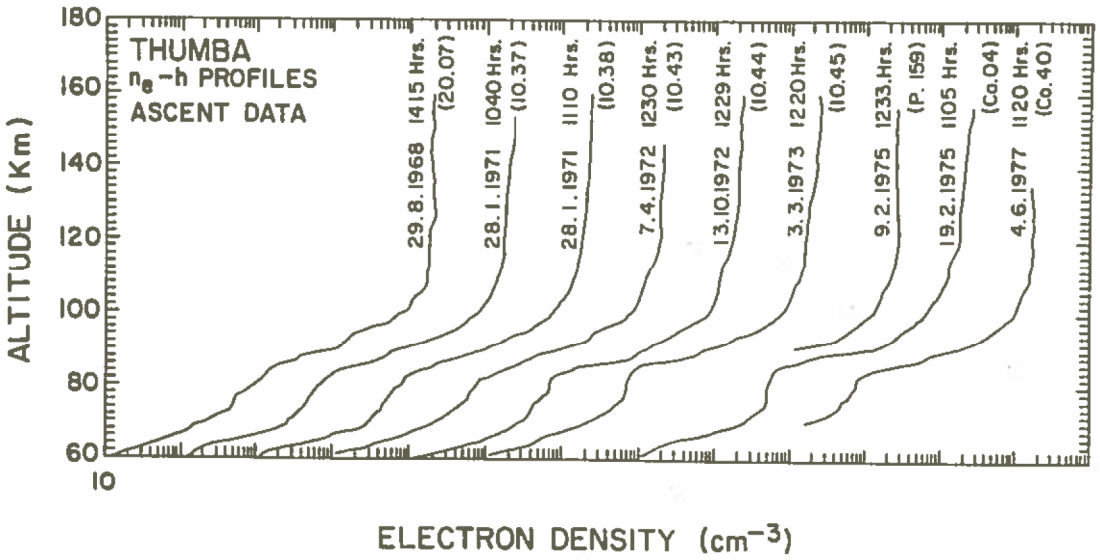


Fig. 2.5 Electron density profiles of nine daytime flights conducted from Thumba during normal electrojet period. Numbers within brackets indicate the flight number. Except for the first flight (No.20.07) all the remaining profiles are shifted by 1 decade (on the X-axis) with respect to the previous flight for viewing convenience (NEJ Profile).

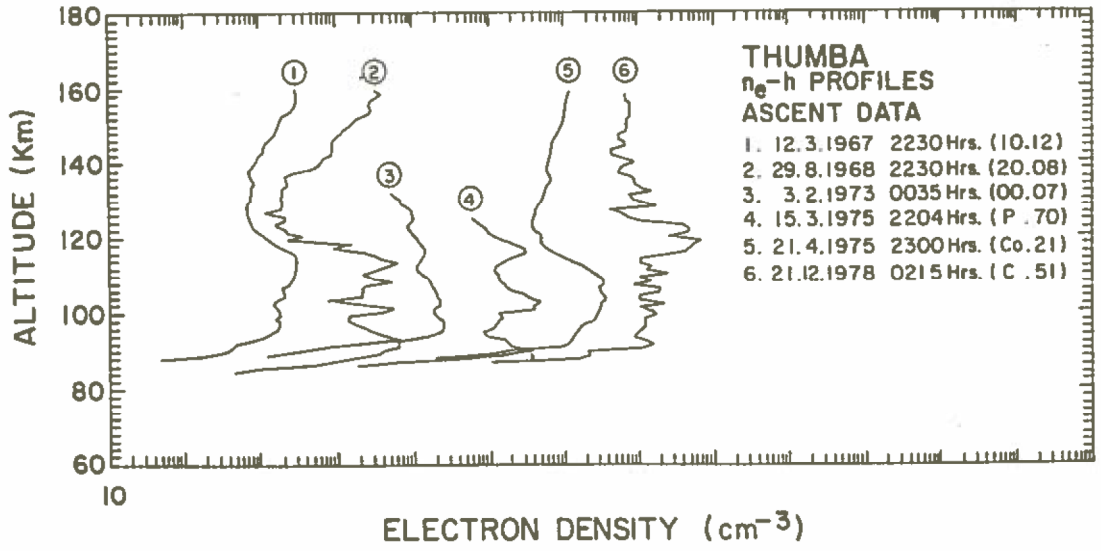


Fig. 2.6 Electron density profiles of six nighttime flights conducted from Thumba. Except for the flight No.10.12 all the remaining profiles are shifted by one decade (on the X-axis) with respect to the previous profile (Nighttime Profile).

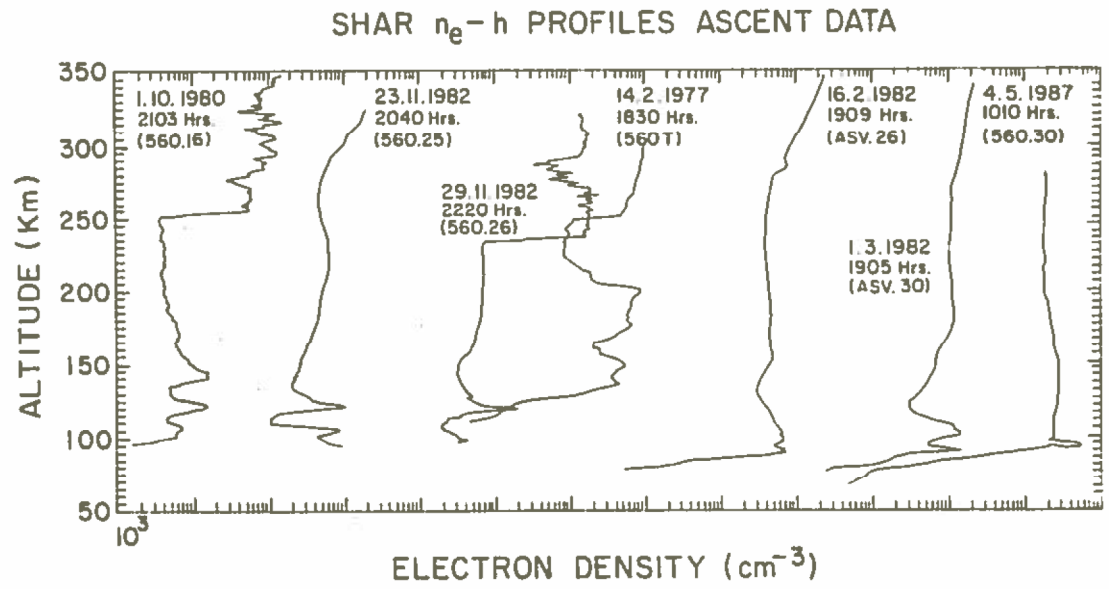


Fig. 2.7 Electron density profiles of the three nighttime, three eveningtime and one daytime flight conducted from SHAR. Except for the flight No. 560.16 all the remaining profiles are shifted by two decades (on the X-axis) with respect to the previous profile (SHAR Profiles).

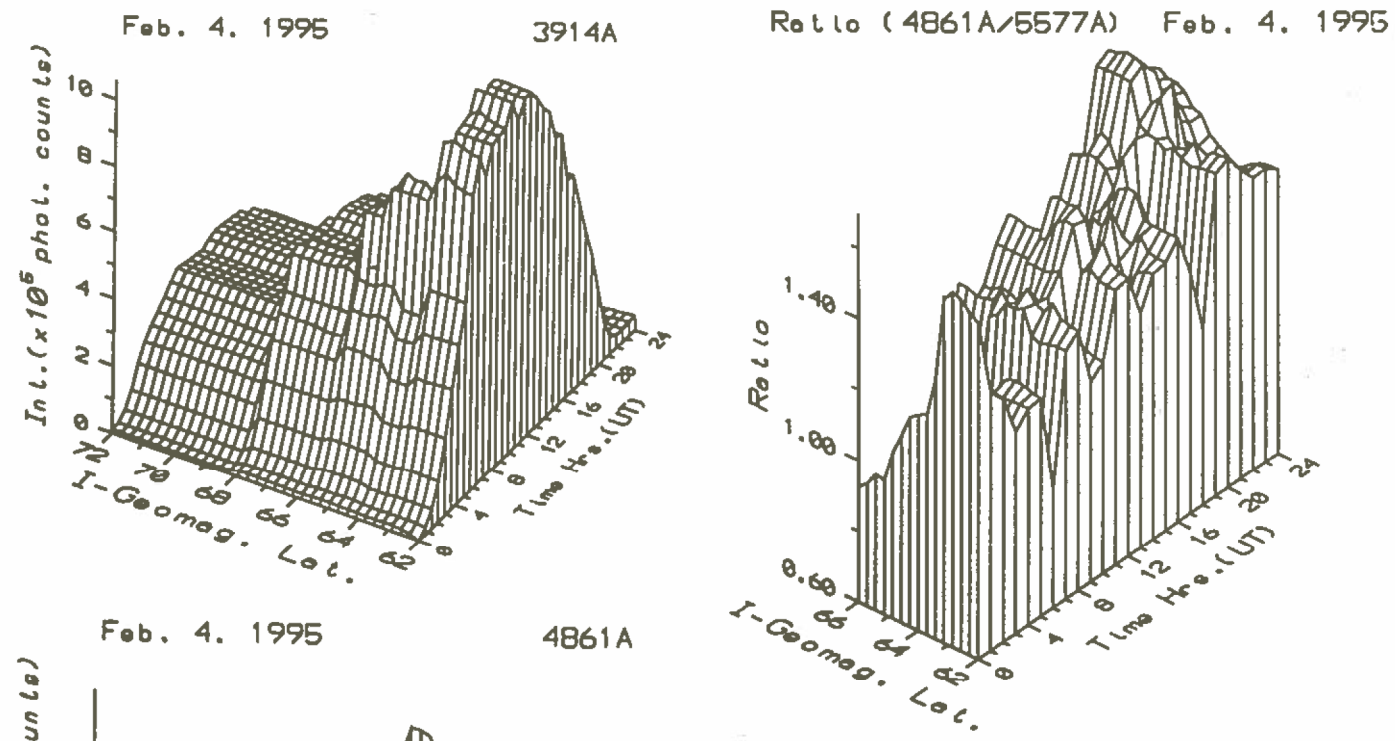


Fig. 2.8 Temporal/spatial variability of (a) high energy electron excited 3914A emission as monitored from the Indian Antarctic Station, Maitri. b) Proton excited 4861 A emission. c) Ratio of 4861/5577 intensities, the former due to proton excitation and the latter due to low energy electron excitation.

Daytime Auroral Emission Measurements from Antarctica

An exploratory programme for the feasibility of making measurements of faint auroral emissions from Antarctica, using an indigenously designed and developed multiwavelength daytime photometer was initiated and the firstever continuous monitoring of auroral emissions were reported last year. The programme was continued during 1994-95 with the addition of north bound scans and additional wavelengths were also monitored. These emissions excited by energetic charged particles, precipitating in the region of the field of view of the photometer, corroborate with the passage of the 'plasma pause' overhead. The geomagnetic field lines, the foot of which passes through the observing station, get mapped to the plasmapause region which incidentally is the boundary between the plasmasphere and the magnetosphere. Narrow latitudinal region of particle precipitation at a preferred time of around local noon were the highlights then. The results obtained from this year's expedition revealed that there are significant differences in the precipitation pattern possibly associated with the solar activity levels. The noontime maximum, though prevalent, was of lesser in magnitude. Large day to day variability was also observed. The spatial dispersion of the high energy electrons, low energy electrons as well

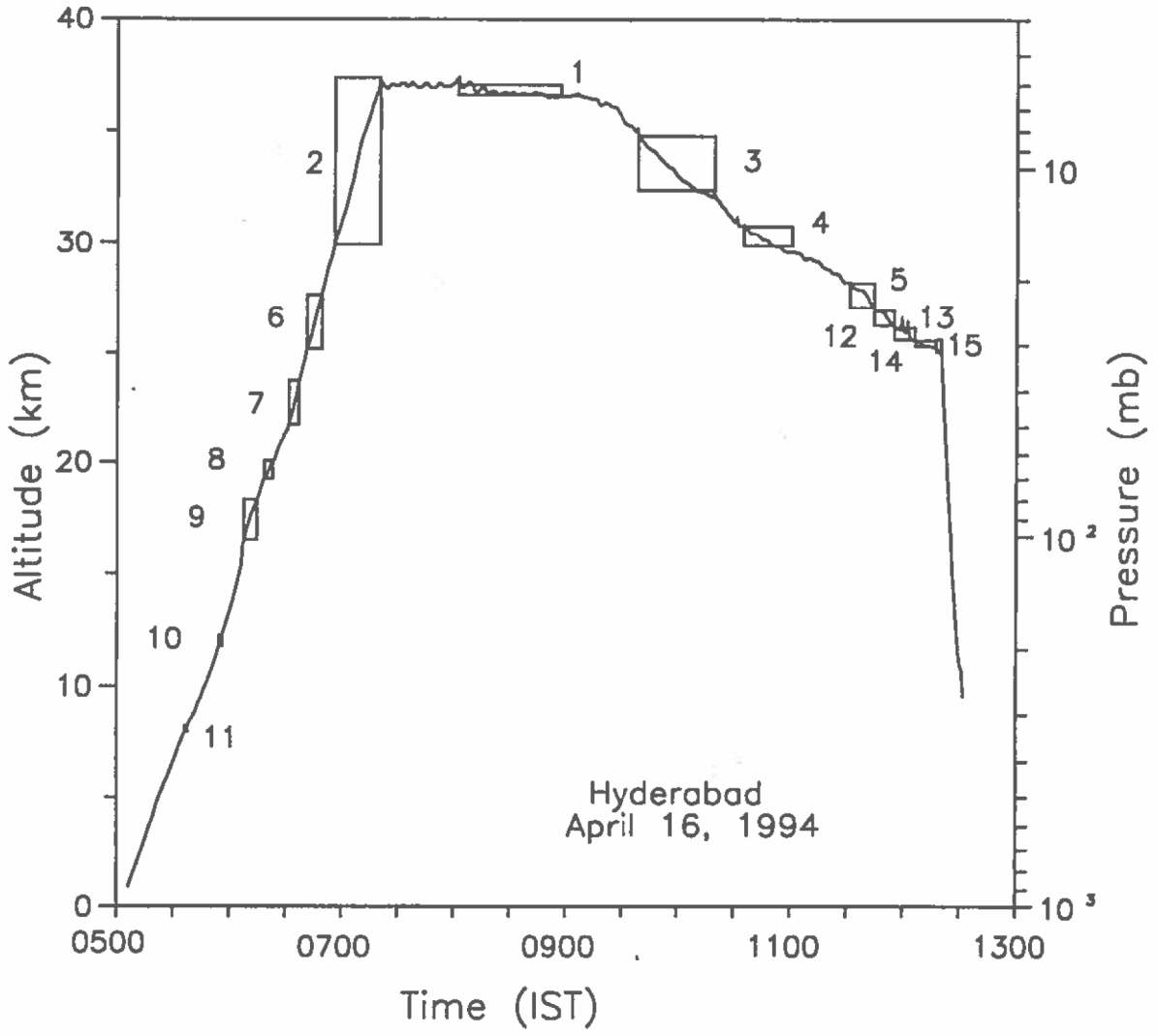


Fig. 2.9 Trajectory of the cryosampler balloon flight conducted from Hyderabad (17° N) on April 16, 1994. The boxes show the air sampling altitudes.

as energetic proton precipitation was also significantly larger. Relative intensities of auroral emissions reveal large regular oscillatory pattern, especially during magnetic storms, indicating the source itself to undergo such variabilities (**Fig. 2.8**). Detailed analysis are under way.

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

MIDDLE ATMOSPHERE

ATMOSPHERIC CHEMISTRY

Vertical Distribution of Trace Gases

The indigenously developed cryogenic air sampler was flown successfully on a 1,46,000 m size balloon from the TIFR balloon launch facility at Hyderabad on April 16, 1994. During the ascent and the controlled descent of the balloon, 15 air samples were collected in the altitude range of 8 to 37 km (**Fig. 2.9**). The balloon was launched at 0506 hrs (IST) and after completion of the ambient air

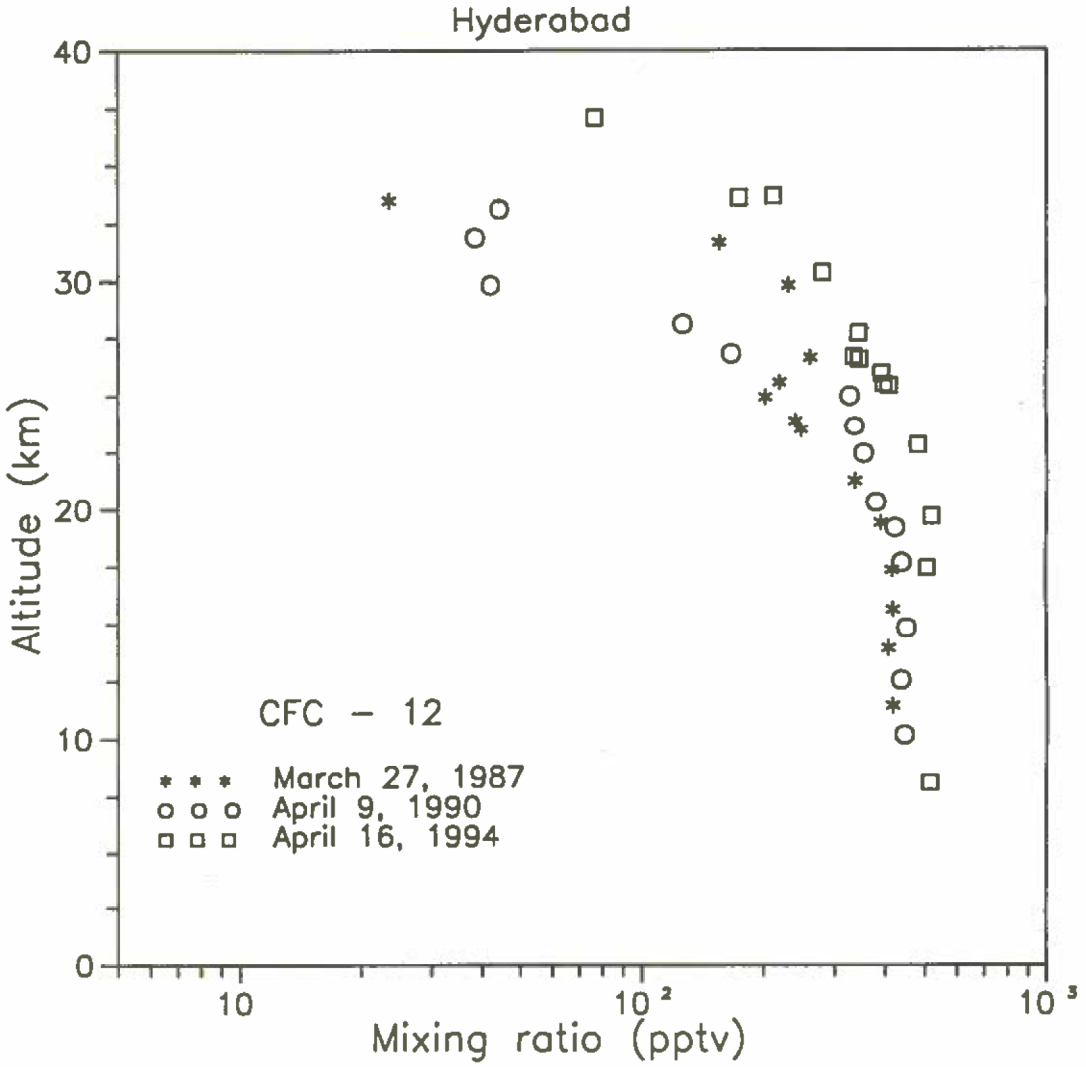


Fig. 2.10 Vertical distribution of CFC-12 measured from the samples collected during the balloon flights made during 1987, 1990 and 1994 from Hyderabad.

sampling the flight was terminated at 1200 hrs. The balloon gondola, consisting of the cryosampler, cryo-control unit, telemetry and telecommand units, was recovered safely.

The collected air samples were brought to PRL for analyses using the gas chromatographic and mass spectrometric techniques. These samples have been analyzed for a variety of gases including CH_4 , CO_2 , CO, N_2O, some CFCs, and Halon-1211, which play important roles in the stratospheric ozone chemistry and greenhouse induced global warming. Vertical distribution profiles of these gases are different from those measured during 1987 and 1990. (**Fig. 2.10**) shows a comparison of the vertical distribution of CFC-12 measured during 1987, 1990 and 1994 from Hyderabad. The distribution profiles of N_2O and CFC-12 etc. show higher concentrations and different slopes particularly in the 18-25 km height region than those measured earlier suggesting stronger upwelling during the time of this balloon flight. However, the influence of change in solar UV radiation due to 11 year solar cycle cannot be ruled out.

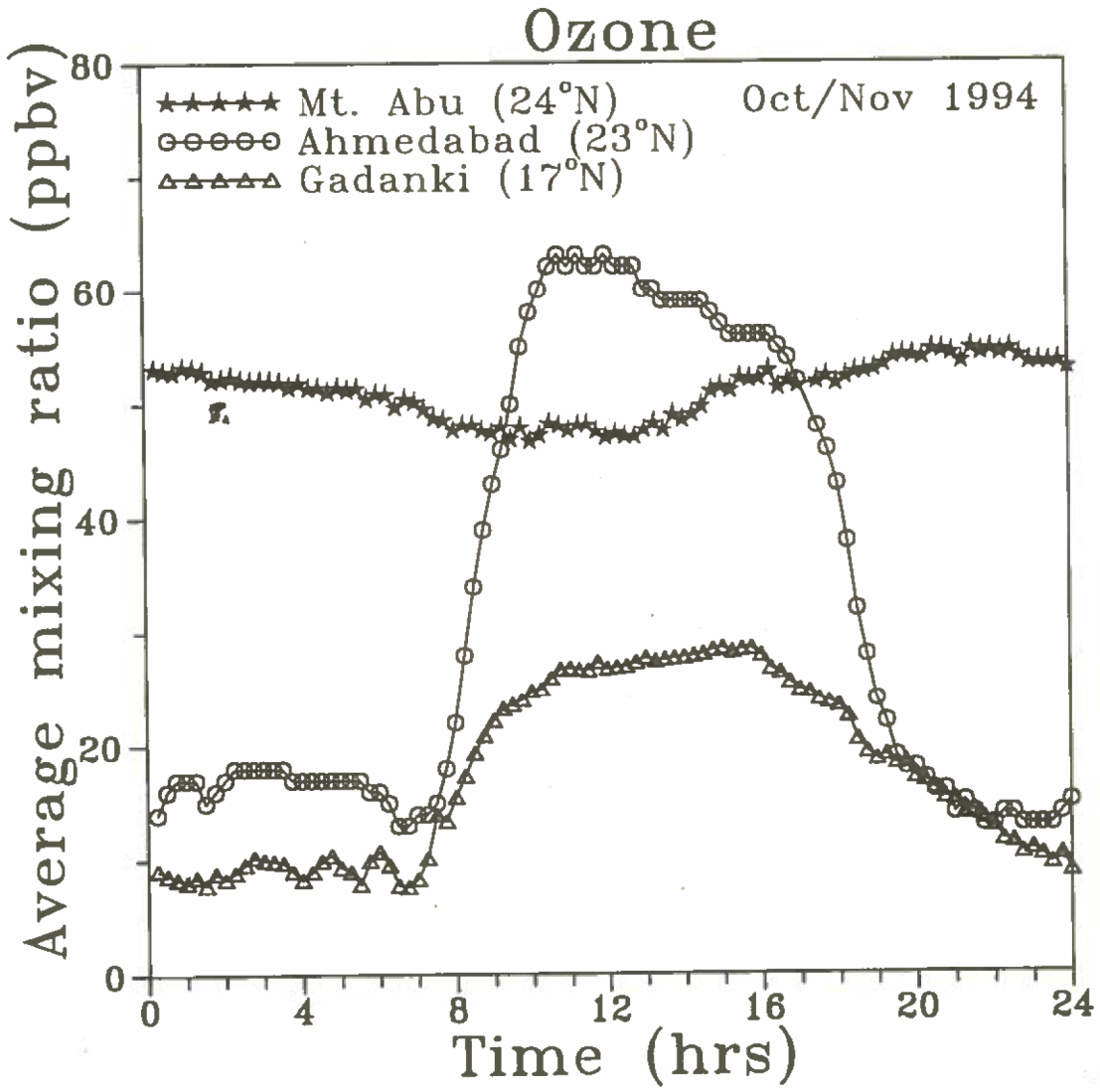


Fig. 2.11 Typical diurnal variations of surface ozone measured at Mt. Abu, Ahmedabad and Gadanki.

A comparison of these results with previous measurements show that the growth rates of some of these compounds has decreased during the 1990-1994 period as compared to that of during 1987-1990 in the troposphere (upto 18 km) where these gases are well mixed. For example, the growth rates of CFC-12 and Halon-1211 were found to be 4% and 15% during 1987-1990 period which have been reduced to 1.6% and 4.5% respectively during 1990-1994 period. This decrease in growth rate is probably due to phasing out of these gases under the Montreal Protocol. These samples are being analysed for other important gases as well.

(P.K. Patra, S. Venkataramani, Y.B. Acharya, B.H. Subbaraya and S. Lal)

Tropospheric O_3 and Precursors

Measurements of surface/tropospheric ozone and its precursors are being made at Ahmedabad (an urban site) and Gadanki (a rural site) under the ISRO/DOS Geosphere-Biosphere Programme. Study of ozone in the troposphere is important because of its role in global

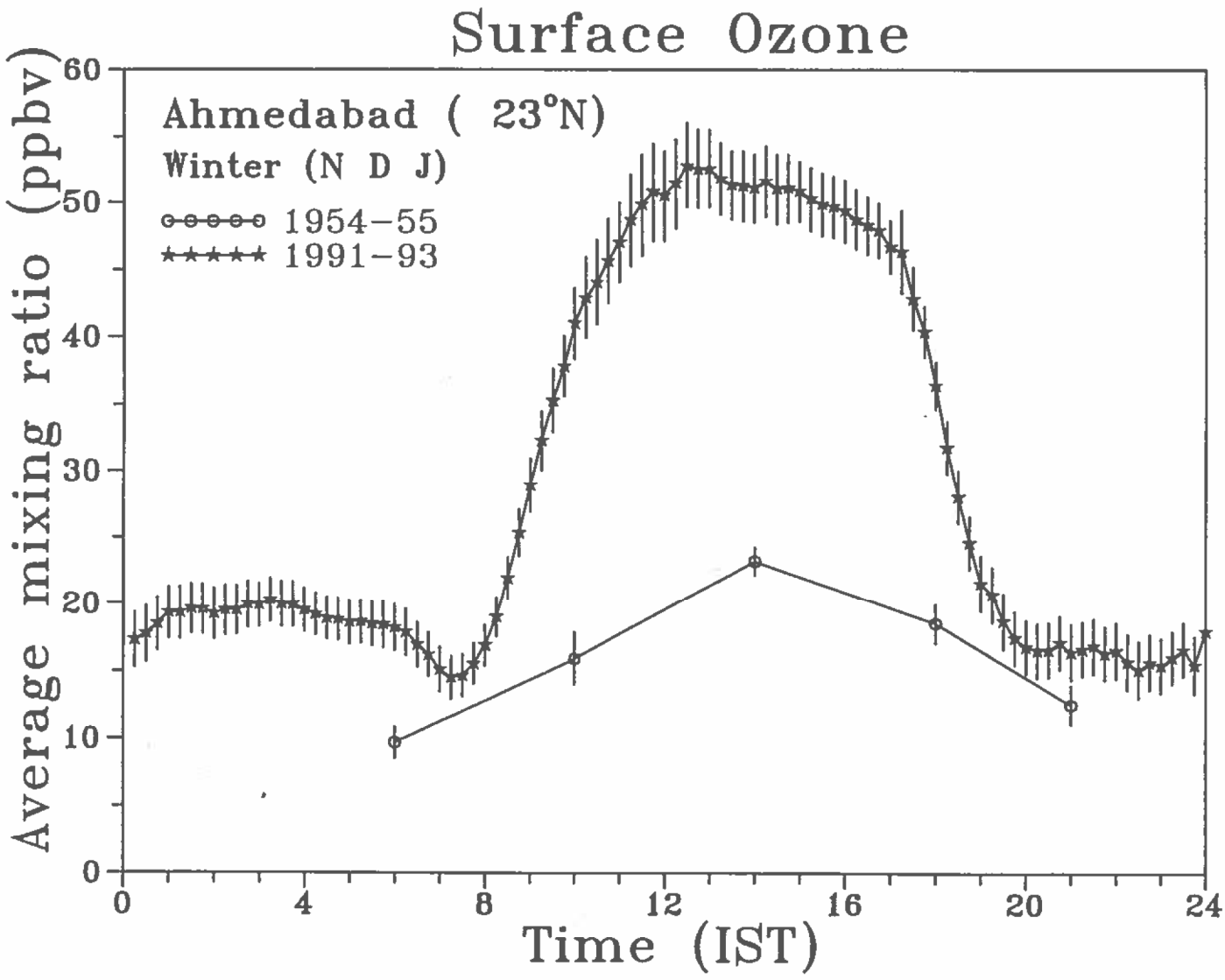


Fig. 2.12 Average diurnal variations of surface ozone measured at Ahmedabad during 1954/55 and 1992/93 periods.

warming through greenhouse effect. Ozone and NO_x measurements at Mount Abu which represents a free tropospheric site have also been carried out during short periods using the instruments of Ahmedabad station. **Fig. 2.11** shows typical diurnal variations of ozone at Mt. Abu,Ahmedabad and Gadanki. While Ahmedabad and Gadanki stations show build up of ozone during day time, there is a decrease in the ozone concentration during day time at Mt. Abu. Not only this, the base line ozone values are higher around 60 ppbv. Ozone concentrations increase upto 2-3 km due to regional photochemical production. Ozone concentration at Ahmedabad increases from a value of about 15 ppbv during night time to more than 60 ppbv during noon hours. The Gadanki data show an increase from about 8 ppbv to 25 ppbv. Measurements of precursors like NO_x , CO and CH_4 show highest concentrations at Ahmedabad followed by Gadanki.

During 1954/55 surface ozone measurements were made at PRL, Ahmedabad for one year using a chemical sensor. A comparison of these measurements with the present measurements has been made to study the changes in the diurnal and seasonal patterns. **Fig. 2.12**

shows a significant increase in the diurnal buildup of ozone at Ahmedabad from 1954/55 to 1992/93. There were no measurements of precursors during 1954/55 but the increase in amplitudes of diurnal and seasonal variations appear to be due to increased levels of precursors. The average ozone increased from a value of 15 ppbv during 1954/55 to 25 ppbv during 1991/93 resulting in a linear increase of 1.4% per year which is significant.

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

Study of Trace Gases in the Arabian Sea

The importance of CO_2 , CH_4 and N_2O in global warming and the significant contribution in atmospheric chemistry of latter two is well recognised. These gases have various (natural as well as anthropogenical) sources in the biosphere. Arabian sea is a nutrient rich region with strong upwelling currents. In order to understand the exchange of these gases at the air-sea interface and for estimating the fluxes of these gases, Department of Ocean Development sponsored programme on Joint Global Ocean Flux Study (JGOFS) has been initiated. Measurements of N_2O, CH_4 and CO_2 were carried out onboard the ORV Sagar Kanya during the April-May 1994 and February-March 1995 cruises in the Arabian sea covering the latitude from 11° N to 22 ° N. Measurements of N_2O and CH_4 were made both in air as well as in sea water collected at different depths at different stations using gas chromatographic techniques.

The results of the April-May 1994 cruise on the vertical distribution of N_2O in sea water show increase in its concentrations from a value of about 6 nM / litre at the surface to a value of about 50 nM / litre around 150 m depth. It decreases sharply in the depth region of 200-250 m but again increases and peaks in the 500-1000 m depth region (**Fig. 2.13**). Super saturation of N_2O is observed at almost all the places even down to 3000 m depth. Around the main peak which lies in the 500-1500 m depth, the super saturation goes as high as 500-600%. There is a large variability with latitude and longitude. These results do not show any appreciable super saturation in the surface water.

CH_4 could only be measured in the second phase of cruise which covered the northern region (16° N to 22° N) of the track. Vertical distribution of this gas in sea water shows a peak in the concentrations around 150 m depth. Its concentration increases from a value of about 2-3 nM / litre to 5-8 nM/litre around the peak region (**Fig. 2.14**). Unlike N_2O, CH_4 shows much higher super saturation around 170-200% in surface water. This shows that even during this quiet period, this part of the Arabian sea is a source of methane.

During the February-March 1995 cruise in addition to the measurements of N_2O and CH_4 , measurements of total carbon dioxide (ΣCO_2) in sea water were also made. These results are being analysed.

(T.K. Sunilkumar, M. Dixit, P.K. Patra, M.M. Sarin and S. Lal)

Pinatubo Volcanic Aerosol Layer Decay Studied using Nd:YAG Lidar at PRL

Time evolution of the stratospheric volcanic aerosol layer produced due to Mt. Pinatubo eruption in 1991, has been studied using a pulsed Nd:YAG backscatter lidar at PRL. The layer has been found to decay with an 1/e folding time of 9 months (**Fig. 2.15**). However, the peak scattering ratio values show a longer decay time of 12.5 months as it has been reported earlier in the case of Fuego and El Chichon eruptions. Faster removal mechanism of aerosols below the peak is found to be the reason for the difference. The average aerosol size distribution for the whole layer has not undergone any considerable change during the decay phase of the layer from one year after the eruption to about three years. The interesting observation made is that the integrated mass and the backscattering coefficient of the layer measured about two years after the eruption is similar to that reported in the case of El Chichon eruption.

In order to study the time evolution of the Pinatubo particles at the stratospheric altitudes, a model study was undertaken. A bimodal lognormal aerosol size distribution signifying an eruption of magnitude of Pinatubo (Model 2 in **Fig. 2.16**), after 45 days of eruption was

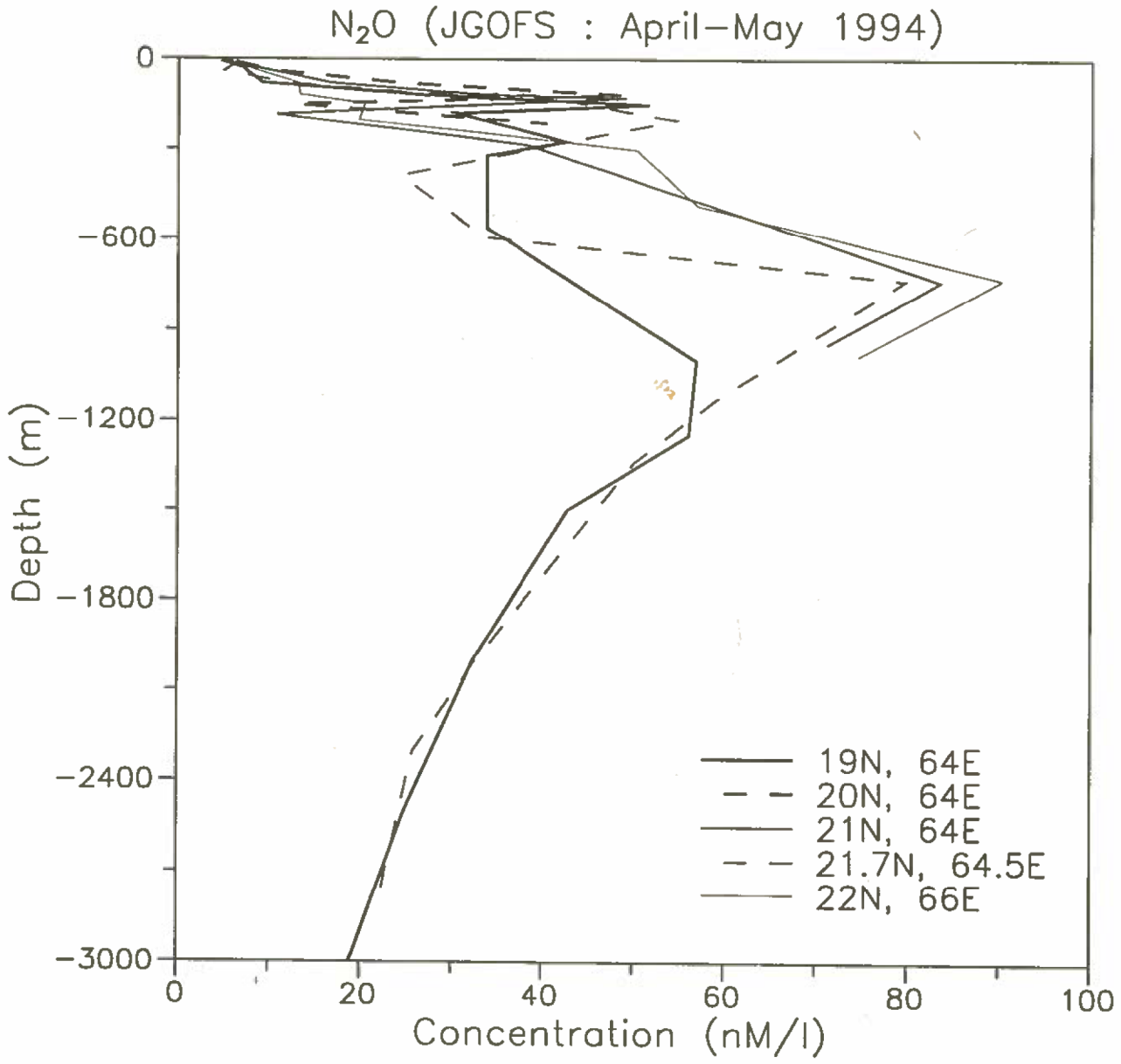


Fig. 2.13 Concentration depth profiles of N_2 O at different locations in the Arabian sea measured during April-May 1994.

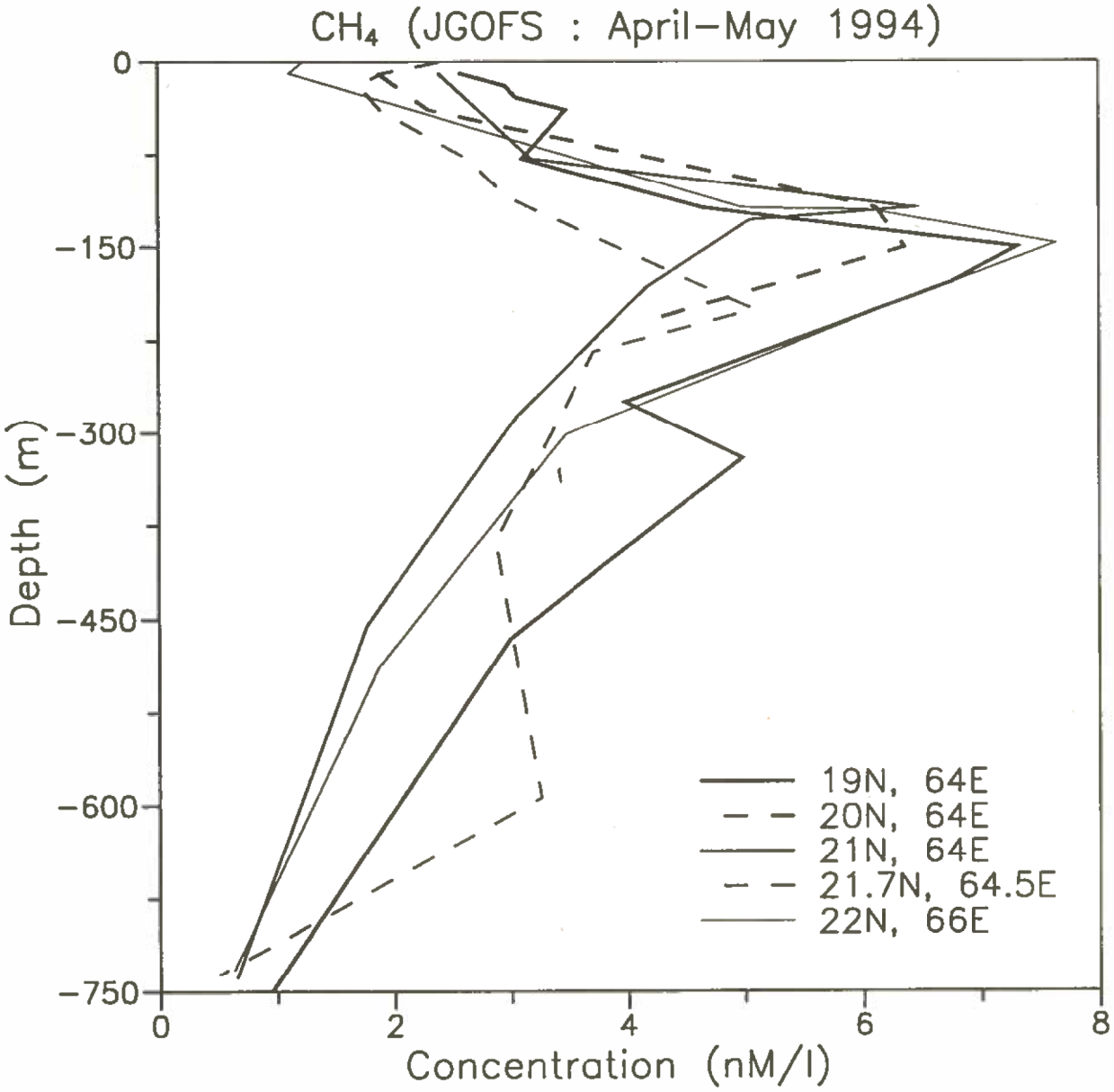


Fig. 2.14 Concentration depth profiles of CH_4 at different locations in the Arabian sea measured during April-May 1994.

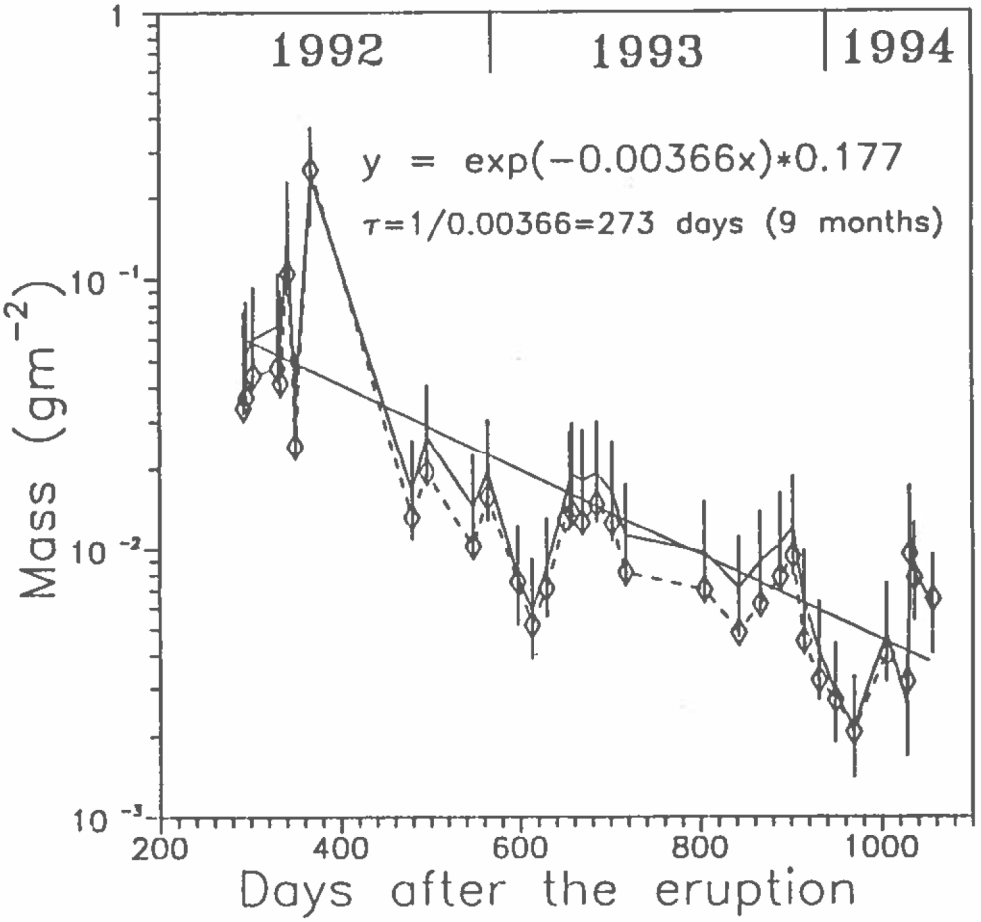


Fig. 2.15 Time variation of Pinatubo aerosol mass in the 17 to 30 km computed from the lidar observations from 1992 to 1994. Vertical error bars are due to the uncertainty in the aerosol mode radius taken as 0.2± 0.1 micron. Dashed curve shows the mass estimated using conversion factors available in the literature.

taken as the initial case and the size distribution was made to evolve for a period of time varying from 2 months to 3 years. The evolved size distributions are used to calculate the aerosol extinction coefficient at 500 nm and then integrated for the whole layer, to study the time evolution of the optical depth of Pinatubo layer. The model results numbered 1 to 3 signify eruptions of widely different magnitudes. The aerosol optical depth obtained using Nd:YAG backscatter lidar shows that the layer has reached background conditions in about 3 years. Both the El Chichon and Mt. Pinatubo decay of the volcanic aerosol layers decayed to background levels in about three years showing that though the amounts of SO_2 injected are very much different, the aerosol microphysical processes of growth, coagulation, have taken place faster giving rise to larger particles, and hence the removal rates of these large aerosols have been faster.

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

Role of Land Surface Processes in Influencing Tropospheric Aerosol Characteristics

Surface aerosol size distribution studies have been started in PRL using a low pressure 14 stage cascade impactor with 6 size ranges below 1.0 μm. Particles are sampled at Ahmedabad, since October 1994. From the mass of particles collected in different stages, the number size distribution (normalized to unit volume of air) of near surface aerosols is obtained. The total mass of aerosol

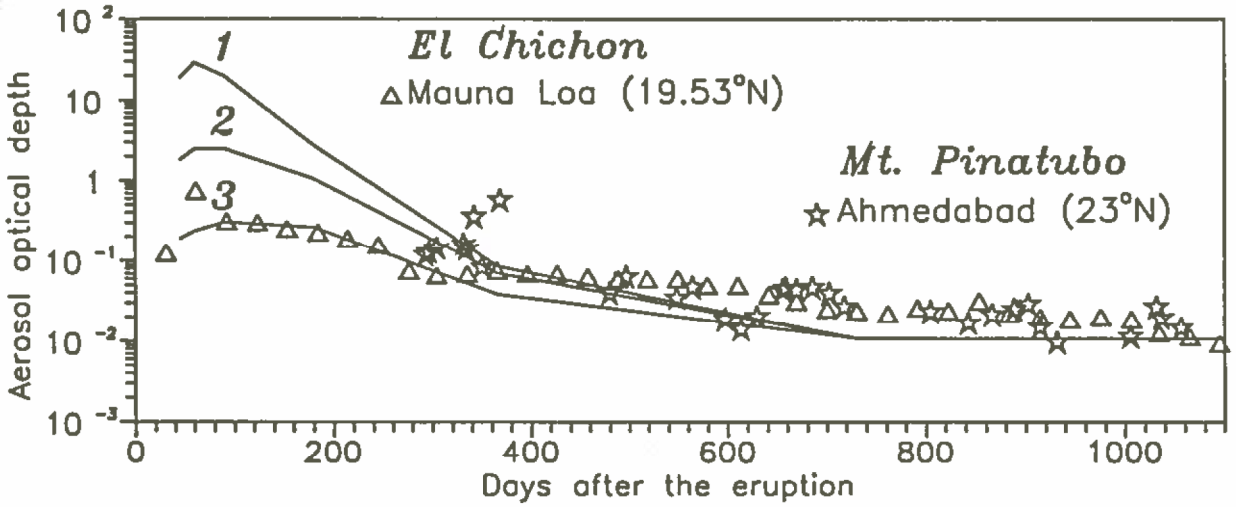


Fig. 2.16 Model results on the time evolution of aerosol optical depths at stratospheric altitudes, for different initial aerosol amounts, corresponding to eruptions of widely varying magnitudes, and the experimental lidar results obtained after Pinatubo and El Chichon, show that the aerosol layers produced at stratospheric altitudes after major volcanic eruptions decay in about 3 years time.

collected, and mass of particles in the 0.1 to 1 μm and 1 to 10 μm size ranges, for four different months are shown in Table 1. An increase in aerosol mass loading from October 1994 to January 1995 is seen.

Table

Month	Total mass	Mass μg/m^3 In the size range 0.1 to 1 μm	In the size range 1 to 10 μm
Oct 94	144	77	44
Nov 94	245	83	94
Dec 94	232	81	115
Jan 95	312	104	116

The number size distribution of near surface aerosols obtained for the four different months are shown in **Fig. 2.17**. The number of particles decreases with increase in particle size. The size index, v, (the slope of the distribution curve) is obtained by fitting a power law function to the values of the number size distribution. Smaller v values in the months of November and December 1994 are due to the dominance of larger size particles (Table 1) and large v values in the months of October and January is due to the dominance of smaller type particles.

Aerosol optical depths were calculated for different wave lengths, from the measured size distribution using Mie theory. Simultaneous Sun photometer observations at six different wave lengths are also made. Attempt is made to compare the aerosol optical depth obtained from Sun photometer measurements to those computed from the measured size distribution using Mie theory.

To gain further insight in to the physical process responsible for the increase in dust loading of the atmosphere a correlative study between aerosol optical depth and different meteorological parameters such as wind speed, wind direction, and surface temperature is underway.

(G. Vijayakumar and A. Jayaraman)

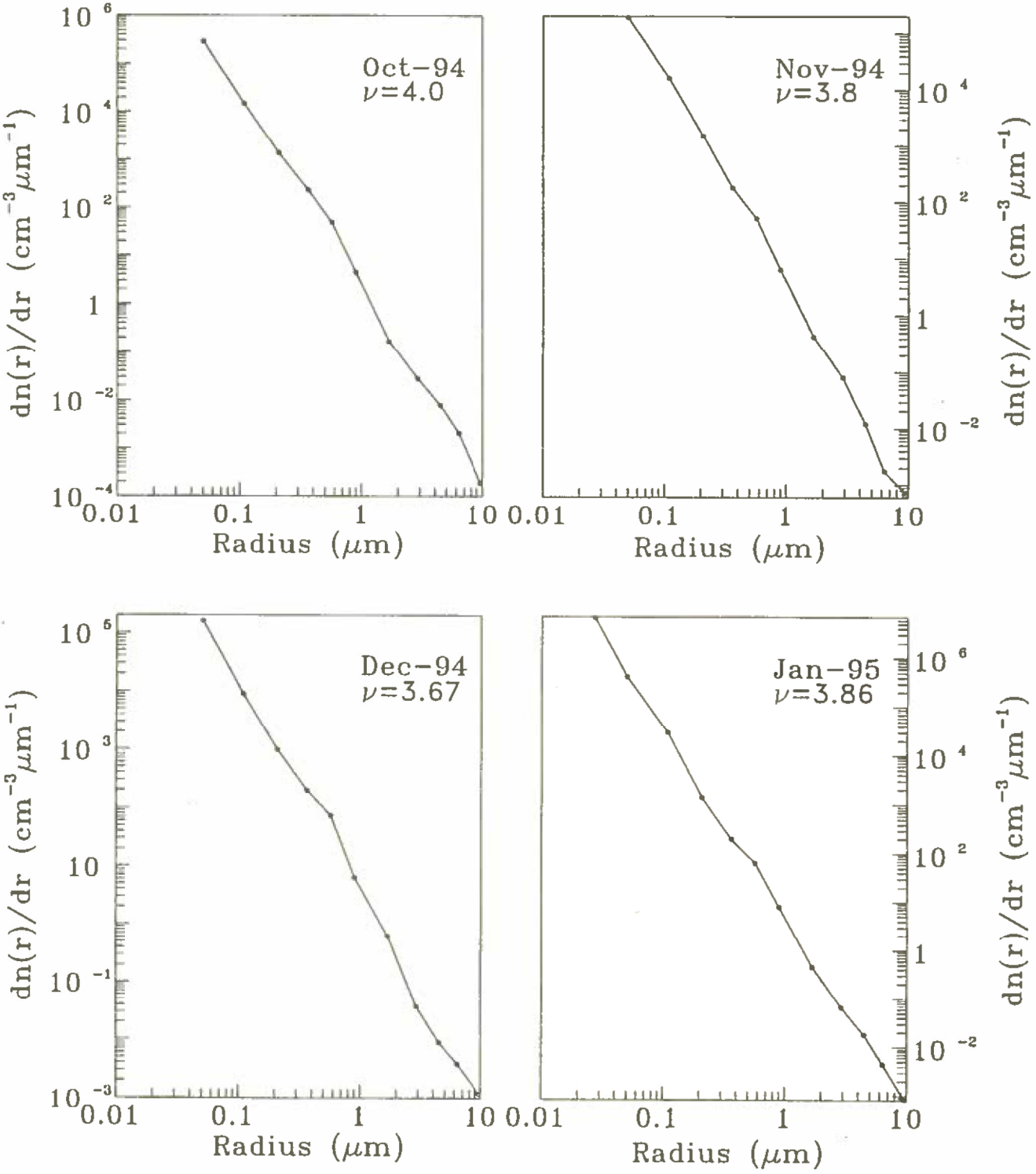


Fig. 2.17 Results of aerosol size distribution obtained from the low pressure impactor experiments made over Ahmedabad during October 1994 to January 1995.

More Results of Model Study on Stratospheric NO_2

We have measured column density of stratospheric NO_2 for a couple of years over Ahmedabad using a ground-based spectrometry technique. Further 1D steady state modelling estimates of the daytime NO_2 column density were also made. These results were also reported last year. However, after sunset, the production of NO_2 stops and steady state condition does not hold good. Hence a time dependent solution has been obtained for the study of night time behaviour of NO_2 . **Fig. 2.18** shows the sunset time and midnight time (six hours after sunset) distributions of NO_2 obtained by us taking the time dependency into account. In this calculation temperature and ozone profiles for low latitude conditions have been used. It is seen that NO_2 has a peak around 25 km altitude. A calculation of (sunrise - sunset)/ sunset ratio of NO_2 at 25 km shows that this ratio is highly sensitive to both temperature and ozone values chosen. **Fig. 2.19** shows the sunrise/sunset ratio of stratospheric NO_2 column density obtained theoretically for two temperature profiles. One profile (— · · —) corresponds to the normal temperature profile and the other (— · —) corresponds to the temperature decreased by 20 K. Agreement with the observations is better in the latter case.

(D.K. Chakrabarty. M. Lal and K. V. Pandya)

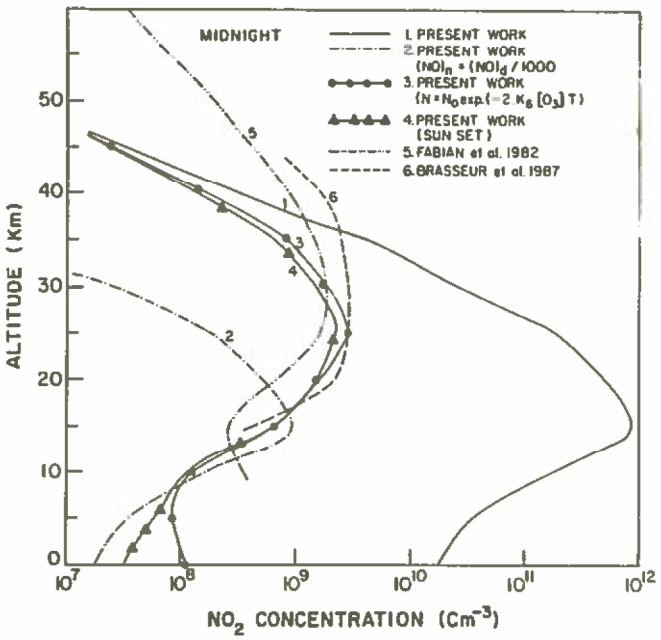


Fig. 2.18 Sunset and nighttime NO_2 profiles.

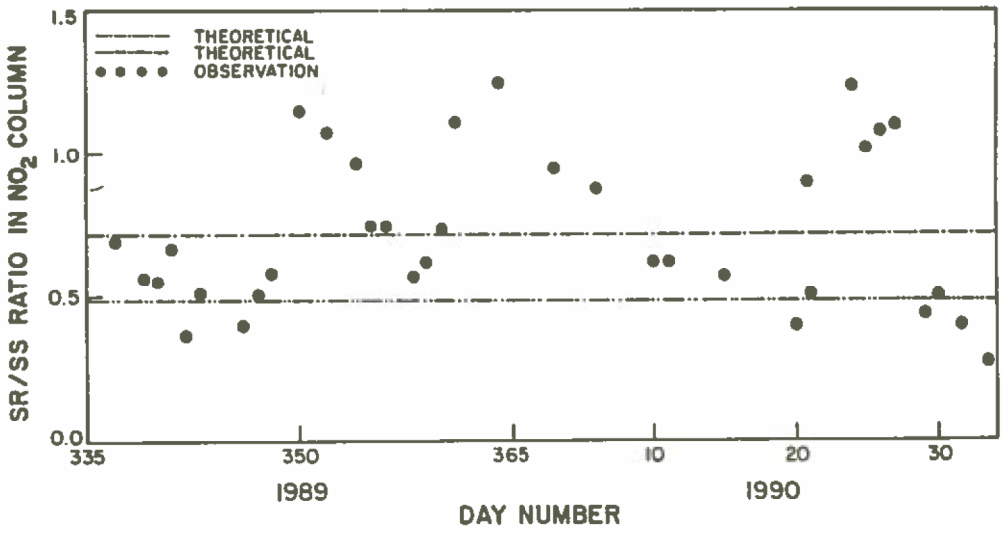


Fig. 2.19 Theoretical and observed values of the SR/SS NO_2 columns.

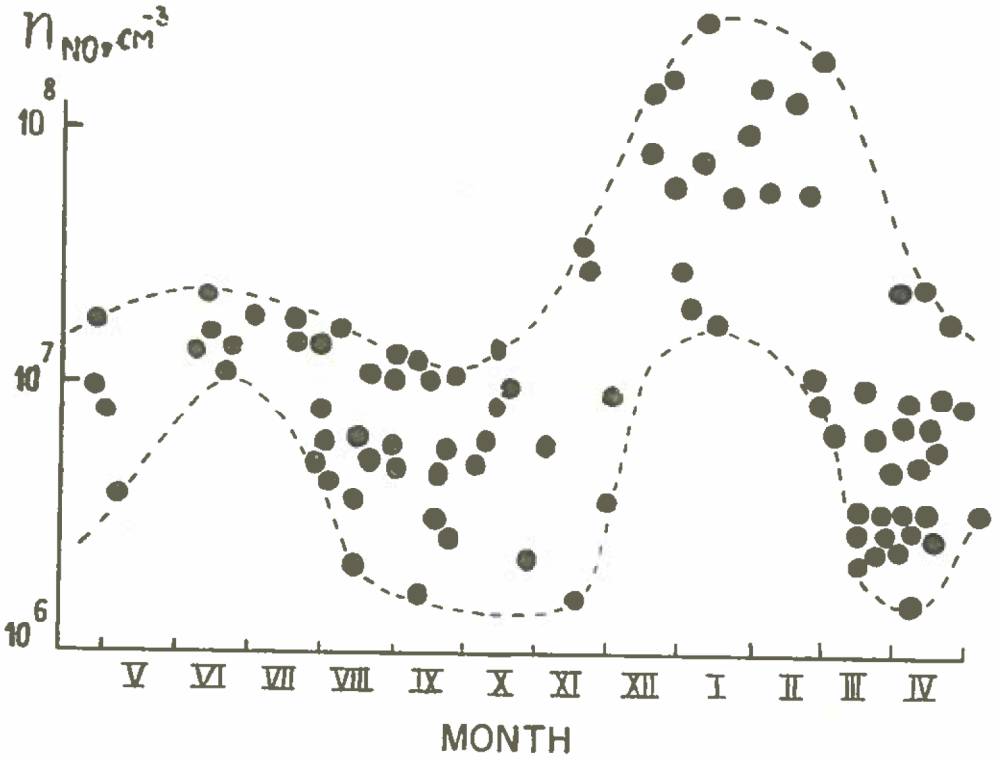


Fig. 2.20 Nitric oxide density over Volgograd during different months at 80 km.

Variability of Nitric Oxide Density in the D-region

A large number of rocket and ground based measurements made over the years by various groups during different levels of solar activity, times of the day, months and geophysical conditions have revealed the presence of different types of variabilities in electron and ion density distributions in the mesosphere and lower thermosphere. It appears that majority of these variations could be explained if a variability in nitric oxide (NO) density is invoked. Direct measurement of this species by rocket is difficult and very expensive. We have, therefore, used a large number of electron density profiles to study the variability of NO. This is possible because, in the middle portion of the D-region, electrons and ions are produced by the interaction of solar Lyman alpha radiation with NO. We have used 78 rocket profiles of Thumba, an equatorial station (8.5° N, 76.8° E). These measurements have been made by the same technique and around the same zenith angle in different months in different years. It has been found that NO density increases by a factor of about 3 at 80 km from minimum to maximum solar activity condition. The analysis also shows a day to day variation in NO density by a factor as large as 2 around the mesopause region. Seasonal variation of NO density at a mid-latitude station, Volgograd (48° N, 46° E) obtained by the same technique shows a maximum in winter and minimum in equinox (**Fig. 2.20**). At low latitudes, no such trend is discernable (**Fig. 2.21**). Here day to day variation appears to be larger than the seasonal variation. An attempt to explain these variations of NO in terms of variation of turbopause height has been made.

(D. K. Chakrabarty)

Development of a Multichannel Photometer to Study Multiple Scattering

Twilight scattered radiations are often used for derivation of several minor neutral constituents and aerosols. These radiations have both single and multiple scattered components. A multichannel photometer has been developed to study the multiple scattering phenom-

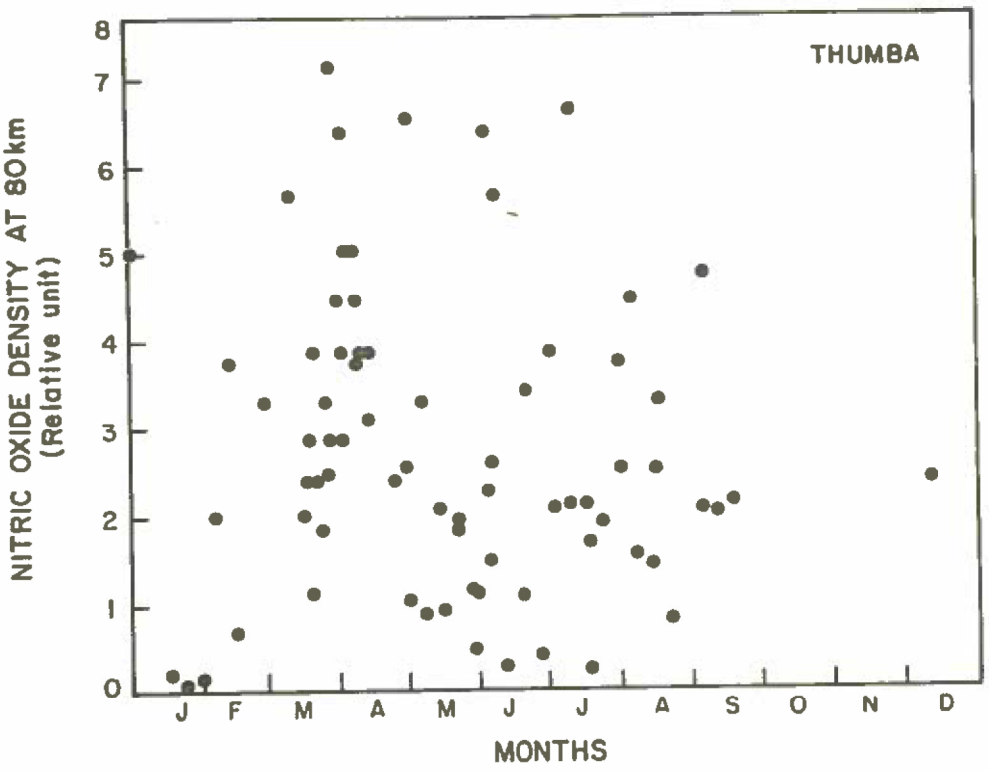


Fig. 2.21 Nitric oxide density over Thumba during different months at 80 km.

enon in the twilight scattered radiation. The photometer has five filters from 400 to 1000 nm. The lower wavelength is sensitive to Rayleigh scattering and the upper wavelength is sensitive to Mie scattering. At different zenith angles during twilight condition, scattered radiations at different wavelengths come from different altitudes. The filters are mounted on a rotating disc. Each filter remains in the field of view of the photometer for 10 seconds. Preliminary data shows that the rate of fall of 440 nm intensity with the increase of solar depression angle is faster than that of 750 nm intensity. We will also study the colour ratio index of different wavelengths.

(M. Lal, J. N. Desai and D. K. Chakrabarty)

Balloon-borne Results on Middle Atmospheric Conductivity

Balloon-borne experiments conducted to investigate stratospheric electrodynamics in the altitude region 20 km to 35 km from Hyderabad have been analysed for seasonal effect for the period (1984-1994). It was observed that the measurements conducted during April months show fluctuations in conductivity values with a period of 20 minutes to 40 minutes, while the experiments conducted in October and January period, do not show such fluctuations. April month is a pre-monsoon period dominated by thunderstorms and lightning activities, while October months are relatively free from such activities. Therefore, it is clear that the thunderstorm activity occurring at tropospheric heights do modulate the conductivity values at stratospheric heights highlighting the electrodynamics coupling between these regions.

(S.P. Gupta and Y.B. Acharya)

Mesospheric VHF Radar Echoes and the Thermal Structure

During the Middle Atmosphere Program (MAP), two powerful ground based techniques have emerged for studying the dynamical features of the middle atmo-

sphere. These are the MST radar and the Rayleigh Lidar. The MST radar is capable of measuring winds in the troposphere - lower stratosphere (< 25 km) and in the mesosphere (70-90 km), while Rayleigh Lidar is capable of studying temperature and density perturbations (gravity waves) in the altitude region of 30-90 km. Thus both the techniques are complementary. At present the only location where these two techniques co-exist is the University of Wales at Aberystwyth, UK. Temperature structure and density perturbations have been studied for several nights from Lidar observations over Aberystwyth. These have been compared with the VHF radar data on many days. Coordinated radar and lidar observations during 1993 have shown that the intense Polar Mesospheric Summer Echoes (PMSE) observed in summer are associated with low mesopause temperatures; the weaker echoes observed in winter seem to be associated with regions of super-adiabatic lapse rate; and echoes are observed both above and below the maxima in temperature inversions commonly observed below the mesosphere. This work was done in collaboration with the University of Wales, Aberystwyth, UK.

(H. Chandra)

Sun Photometry using Photodiode Open Circuit Voltage Measurements

A simple technique is explored in which the open circuit voltage of a photodiode measured using a simple digital multimeter to monitor the solar irradiance and atmospheric optical depths. The experimentally obtained I-V characteristics of photodiode is found to be different from the generally known I-V characteristics of a diode. A suitable polynomial is then fitted to the observed characteristics which is used for Langley plot. The advantage of this technique is that the photometer consists of only an optical interference filter, photodiode and a digital multimeter, and the electronics circuitry otherwise needed in a conventional photometer is avoided. This makes the system very simple, cost effective and versatile even for non professionals to handle.

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

LABORATORY ASTROPHYSICS

Temperature Dependence of Photoabsorption Cross sections of Carbon Tetrachloride

Photoabsorption cross sections for carbon tetrachloride have been measured in the spectral region 186-240 nm for temperatures ranging from 200 to 300 K at an interval of 20 K. These measurements have been carried out with an accuracy of ±4.1% at an instrumental resolution of 0.1 nm. The cross sections obtained in the present experiment have been compared with other measurements wherever possible. However, data on quantitative measurements of photoabsorption cross sections at different temperatures has been scarce. Until now the photoabsorption cross sections for carbon tetrachloride have been reported only at room temperature. The present work is an attempt to take up such measurements at other temperatures between 200 and 300 K.

The new experiment designed and fabricated in the laboratory to make such measurements consists of an argon mini-arc light source giving continuum from 110 to 350 nm, a one-meter near normal incidence grating monochromator, a beam splitter, absorption chamber, cooled photomultipliers operated in the counting mode and proper amplifiers and fast data acquisition system. The beam splitter has been designed to monitor photon beam intensity during the experiment. The length of the absorption chamber can be varied from 70 to 90 cm using two long quartz tubes at its two ends. These tubes which are closed at the outer ends by suprasil quartz plates could be moved in and out of the absorption chamber. The double-jacketed absorption chamber can be cooled and the temperature could be varied from 200 to 300 K to an accuracy of ±0.5 K.

The photoabsorption cross sections measured in the present experiment have been found to decrease with decrease in temperature by a factor which depends upon the molecular structure of the target gas and the incident photon wavelength. The temperature dependence of cross section has been found to be most significant at low temperatures and in spectral regions of low absorption. The temperature effect vanishes in the region of higher

absorption i.e. at lower wavelengths.

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

Emission from Laser Produced Plasmas

A new system has been designed and fabricated in the laboratory to carry out spectroscopic studies of laser produced plasma for different targets. To start with, mild steel has been used as the target to produce an expansion plume by irradiation of well focused laser beam from xenon chloride excimer laser. The spectroscopic study of such a plume has confirmed the presence of some emission lines superimposed over a well-defined and highly intense continuum radiation extending from 145 to 185 nm.

The laser produced plasma system consists of excimer laser (Lambda Physik), optics for focussing the laser beam on a metal target, the arrangement for rotating the target which could otherwise get pitted because of long exposure from laser pulses, vacuum chamber for housing the rotatable target system, a 0.5 meter Czerny-Turner evacuable monochromator, a fast photomultiplier and a high sampling rate digital oscilloscope for data acquisition. The whole system is capable of studying the line emission/continuum spectra produced by the expansion plume in the spectral region ranging from 115 nm to higher wavelengths.

After having studied the emissions, both line and continuum, emanating from different parts of the expansion plume, it is proposed to study some reaction chemistry of this plume with different gas molecules. It may be possible that this background gas-induced emission is enhanced several times. Such a study would give a better insight about the possible mechanism for the reaction occurring in the plasma.

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

Fluorescence Spectroscopy of Weak Fluorescing Systems

A new experiment has been designed and fabricated in the laboratory to study the fluorescence spectra of molecules having small photoabsorption and fluorescence cross sections. One such system is NO_2 which is present in the earth's atmosphere as a minor constituent. Such a weak fluorescing system cannot be investigated by the conventional UV or VUV line and continuum light sources which are too weak to cause excitation in the system. That is why a high powered tunable laser has been used to study such systems.

The major components of the experiment include the excimer laser-pumped dye laser, laser beam expander, absorption cell with beam collimator, proper optics to gather fluorescence emission with or without fibre optics, 0.5 m monochromator, fast photomultiplier for detection of signals and a PC-coupled digital storage oscilloscope having high sampling rate capability. The absorption chamber is evacuated by a set of pumps viz. diffusion, roots and mechanical pumps. All the subsystems required in the experiment are ready and have been integrated in the over-all system. Work is being done right now to reduce the scattered light signal from the walls of the chamber and the metal and optical components. The experiment would be ready for use in the near future.

To start with, it is proposed to study the fluorescence spectra of NO_2 at incident photon wavelengths ranging from 320 to 400 nm. It is intended to measure the relative production cross section for different product states as a function of incident photon wavelength.

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

PLANETARY/COMETARY ATMOSPHERES

Polar Ion Exosphere of Mars

This is the continuation of earlier work where a model for the polar ion exosphere of Mars was developed on the basis of polar wind acceleration process. The

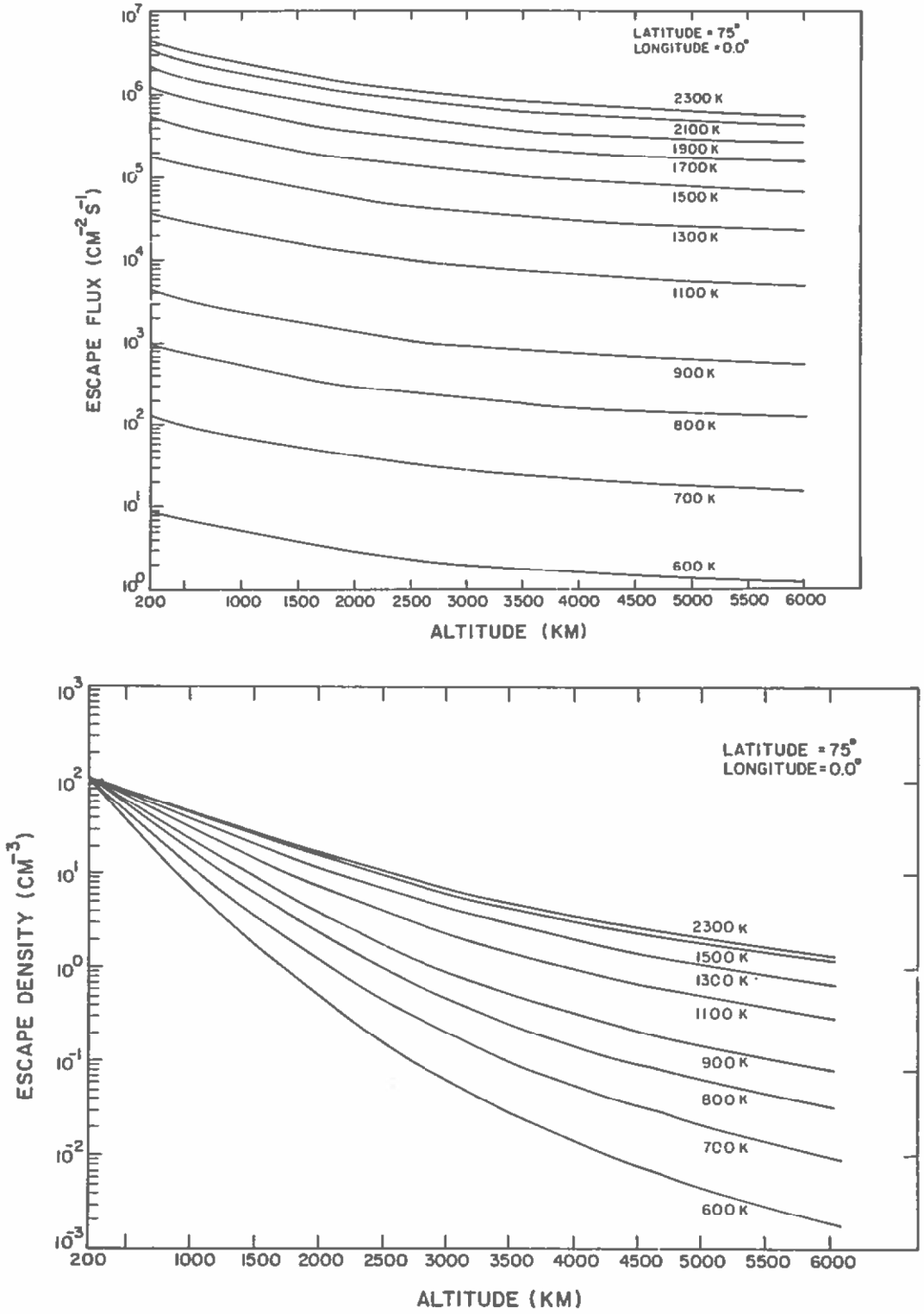


Fig. 2.22 Escape flux (Top) and escape density (Bottom) of O^+ at T = 600 K to 2300 K in O^+ - e exosphere of Mars crossing the baropause at latitude 75° and longitude 0° in anti-solar direction.

model is extended now and the calculations of escape flux and density of oxygen ions and electrons through the plasmasheet of Mars are made at temperatures T= 600 K to 2300 K for latitude 75° and longitude 0° (**Fig. 2.22**). The escape flux (top) and density (bottom) increase with increasing temperatures. Above 2300 K, they do not increase because the increased electron temperature leads to an increased charged separation electric field which accelerates O^+ ions thereby decreasing density of O^+ at the exobase, thus counteracting and maintaining the flux and density at the saturation point.

During first and second orbit of Phobos 2, the first plasma study in the Martian magnetotail was carried out by solar wind Plasma Instrument (TAUS) and Automatic Space Plasma Experiment with Rotating Analyser (ASPERA). According to the data of TAUS and ASPERA experiments, the populations of O^+ in the second orbit was 2-4 x 10^6 cm^{-2} s^{-1} at 1:00 UT in the magnetotail while more energetic fluxes of the order ~ 2-4 x 10^7 cm^{-2} s^{-1} were observed in the plasmasheet at 2:00 UT. In the first orbit the ion fluxes were as 7 x 10^7 cm^{-2} s^{-1} at 19:00 UT and ~ 10^7 cm^{-2} s^{-1} at about 20:30 UT in the plasma sheet. In both the orbits at about 19:00, 22:00 and at 1:47 UT, the ASPERA data shows the maximum O^+ flux which exceeds 10^7 cm^{-2} s^{-1}. During the second orbit, ASPERA experiment observed the density of O^+ ~ 2 and 6 cm^{-3} at about 1:06 and 5:37 UT respectively. The average value of flux and density of O^+ in the magnetotail of Mars has been reported 2 x 10^6 cm^{-2} s^{-1} and 0.8 cm^{-3} respectively. Our model calculations show very close agreement with these observations. Thus, the polar wind acceleration process is responsible for the ions escape through the polar region similar to that found in the earth's polar magnetosphere.

(S. A. Haider)

Chemistry of Atomic Carbon in Comet Halley

Various experimental data acquired during the visit of Halley's comet in 1986 have shown that the amount of carbon produced due to photo dissociation of parent carbon bearing species is not ample enough to explain the observations. This requires the presence of an additional source of atomic carbon. One of the possible source could be auroral type activities resulting from the precipitation of high energy auroral electrons of solar wind origin, the evidence of which have been inferred from many observations in comet Halley. To resolve the carbon crisis in the coma of comet Halley the coupled chemistry transport model is developed and the production and loss of atomic carbon due to different sources are studied in detail. The model atmosphere in the chemistry is taken as 80% H_2O and 1.5% NH_3, 0.5% CH_4, 3%

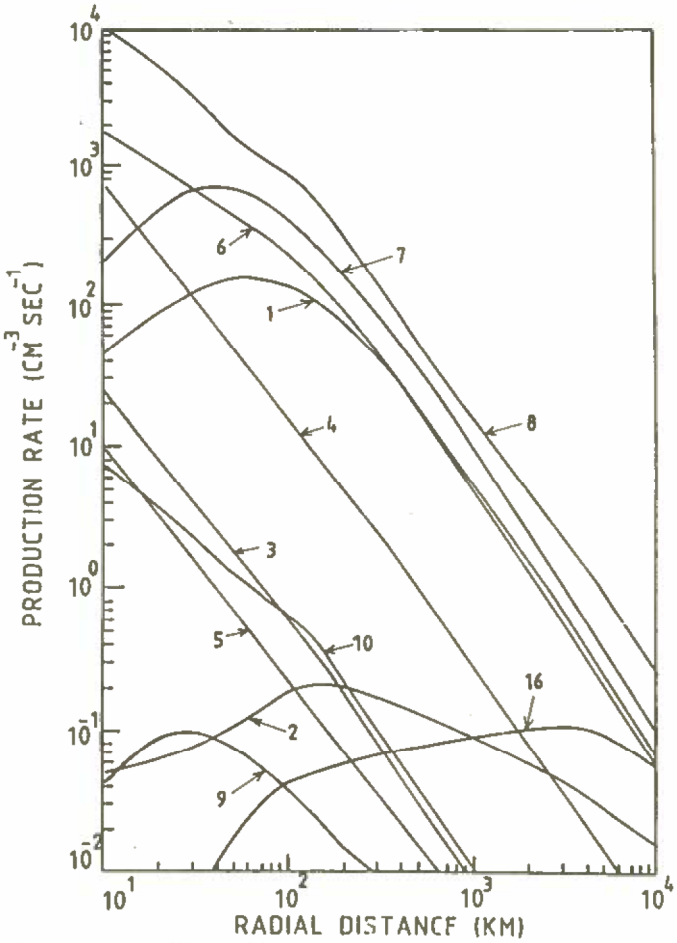


Fig. 2.23a Radial profiles of neutral atomic carbon production. Key : (1) photodissociation of CO; (2) recombination of CO^+ ; (3) $C^+ + NH_3$ reaction; (4) $C^+ + H_2O$ reaction; (5) $C^+ + CO_2$ reaction; (6) $C(^1D) + H_2O$ reaction; (7) photoelectron impact dissociation of CO; (8) auroral electron impact dissociation of CO; (9) photoelectron impact dissociation of CO_2 ; (10) auroral electron impact dissociation of CO_2 ; (16) radiative deexcitation of $C(^1D)$.

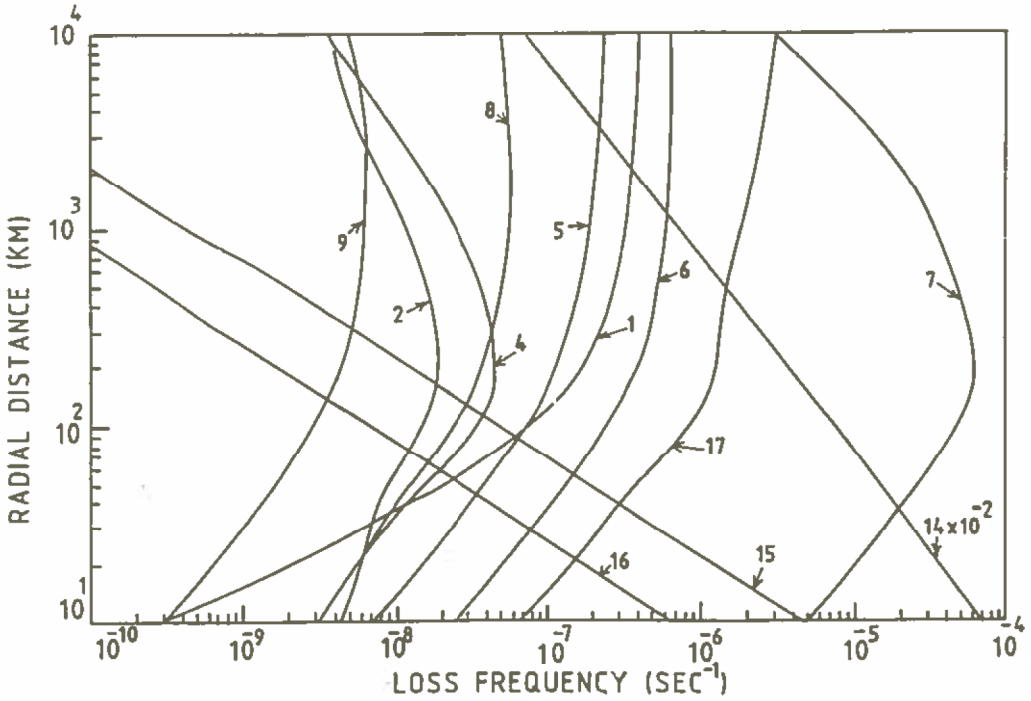


Fig. 2.23b Radial profiles of the Loss frequency of neutral atomic carbon due to reaction: (1) photoionization of C; (2) $C + O_2^+$; (4) $C + CH_3^+$; (5) $C + OH^+$; (6) $C + H_2O^+$; (7) $C + H_3O^+$; (8) $C + HCO^+$; (9) $C + CO_2^+$; (14) C + OH; (15) $C + CH_4$; (16) $C + CO_2$; (17) auroral + photoelectron; curve 14 is plotted by dividing by 100.

CO_2 , and 20% CO (all with respect to H_2O) which is constrained by various observations in Halley. The other species of O and C are obtained through the computation while the densities of H and OH are adopted from other literature. **Fig. 2.23a** represents the profiles of production rates of atomic carbon from various sources. Auroral electron impact dissociation of CO is the dominant source of carbon production followed by photoelectron impact dissociation of CO. The third major contribution comes from photodissociation of CO and the deexcitation of $C(^1D)$ through reaction with H_2O, both of which are almost equal in magnitude except that they occur deep (< 200 km) in the coma where the deexcitation of $C(^1D)$ dominates. Production of C through ion neutral chemistry is mainly by charge exchange reaction of C^+ with parent neutrals, but all of these are more than an order of magnitude lower than the above source. The model study suggests that dissociative recombination of CO^+ as a source of carbon atoms is insignificant at least for distances less than 10^4 km. The profiles of loss of atomic carbon by different processes are presented in **Fig. 2.23b.** Loss of carbon is predominant via transport mechanism. The other significant loss process is through the reaction with OH, but this process is about an order of magnitude less than the transport loss. Electron impact ionization of C is not found to be an appreciable loss process.

(S.A. Haider)

Earth Sciences and Solar System Studies

OCEANOGRAPHY AND CLIMATE STUDIES

Research activities of the Oceanography and Climate Studies area have continued under three broad topics: (i) Palaeoclimate and Environmental studies, (ii) Oceanography and (iii) Hydrology, Limnology and Weathering. In addition, the radiocarbon facility of the area continued to provide the much needed chronological data for archaeological and geological samples supplied by various Universities/ Institutions.

PALAEOCLIMATE AND PALAEOENVIRONMENTAL STUDIES.

Deserts and Desert Deposits

Thar Desert: We have continued our programme to study the origin and evolution of the Thar Desert and its relation to global climatic change. The history of contraction/expansion of Thar holds clues to palaeomonsoon behaviour over India. Deep sand profiles in Thar are being studied to address questions on desert expansion and periods of extended aeolian activity. In this context, Khudala section in Barmer was studied with isotopic and clay mineral analysis. These data along with the thermoluminescence chronology suggest a sea level control on the deposition of the basal gravel correlatable to oxygen isotope stage 5e. The data also indicate a humid phase at 35-40 ka (kilo annum), which together with our earlier studies suggest a regionally extensive humid phase in W. India. The evidence of a minimal aeolian/fluid aggredation remains as yet enigmatic and may have an underlying tectonic component altering the stream behaviour with a climatic control on eustatic sea level change.

Other Deserts: To evolve a regional scenario of the behaviour of SW monsoon through time, a new programme to document the climatic changes in Oman and Arabian desert was initiated with the help of UNESCO. Oman lies in the SE margin of the Arabian Peninsula and the presence of landforms such as the Wadis (fluvial deposits), Sabkhas (saline and fresh water lacustrine sequence), aeolianites (cemented carbonate dunes) and the sand dunes suggest that the region experienced a fluctuating climatic regime ranging from warm/humid to cold/dry. A major dune field (the Wahiba sands) oriented in the direction of the SW monsoon appears to hold promise to provide an evolutionary record of the SW monsoon. A suite of 40 samples from the above mentioned deposits was collected for luminescence dating and assign a chronology to the associated climatic events.

Loess-Palaeosol Sequences: As a part of the continuing programme on global loess palaeosol sequences, thermoluminescence chronology of the Karamaydan (Tadjikistan) loess palaeosol sequence was established. The results indicated that the pedocomplex PK-II of this sequence represents the last interglacial epoch, which contrasts with the existing correlation of the younger soil horizon PK-I to the oxygen isotope stage 5e, based on mineral magnetic and magnetic polarity data. The luminescence based chronology also indicates a regionally extended (seen in Kashmir and in China) humid phase about 50-80 ka ago, which grossly agrees with the results from the Thar.

With a view to understand the depositional history of loess palaeosol sequences and their relation to global climate, the available data on loess palaeosol chronology was reviewed and synthesised. The spectral analysis of the accumulation episodes of loess provided several important inferences such as : (i) the peak in loess accumulation occurred at ~ 17 ka and not at the peak of the last glacial epoch at ~ 21.5 ka as has been assumed generally (ii) the loess accumulation is episodic, with periods of hiatus and/or substantially reduced accumulation (**Fig. 3.1**). This study suggests that direct correlation of loess palaeosol record with deep sea oxygen isotopic data may need a closer scrutiny and that the observed Milankovitch periodicities in the loess records may be somewhat fortuitous.

The loess-palaeosol sequences were also used to investigate the problem of the age under-estimation. It was observed that no matter how high the true age of a loess sequence is, its luminescence age is saturated at about 100 ka, despite the fact that the theoretically inferred stability of luminescence signal is ~ 10 Ma. From a study of the changes in TL response during laboratory

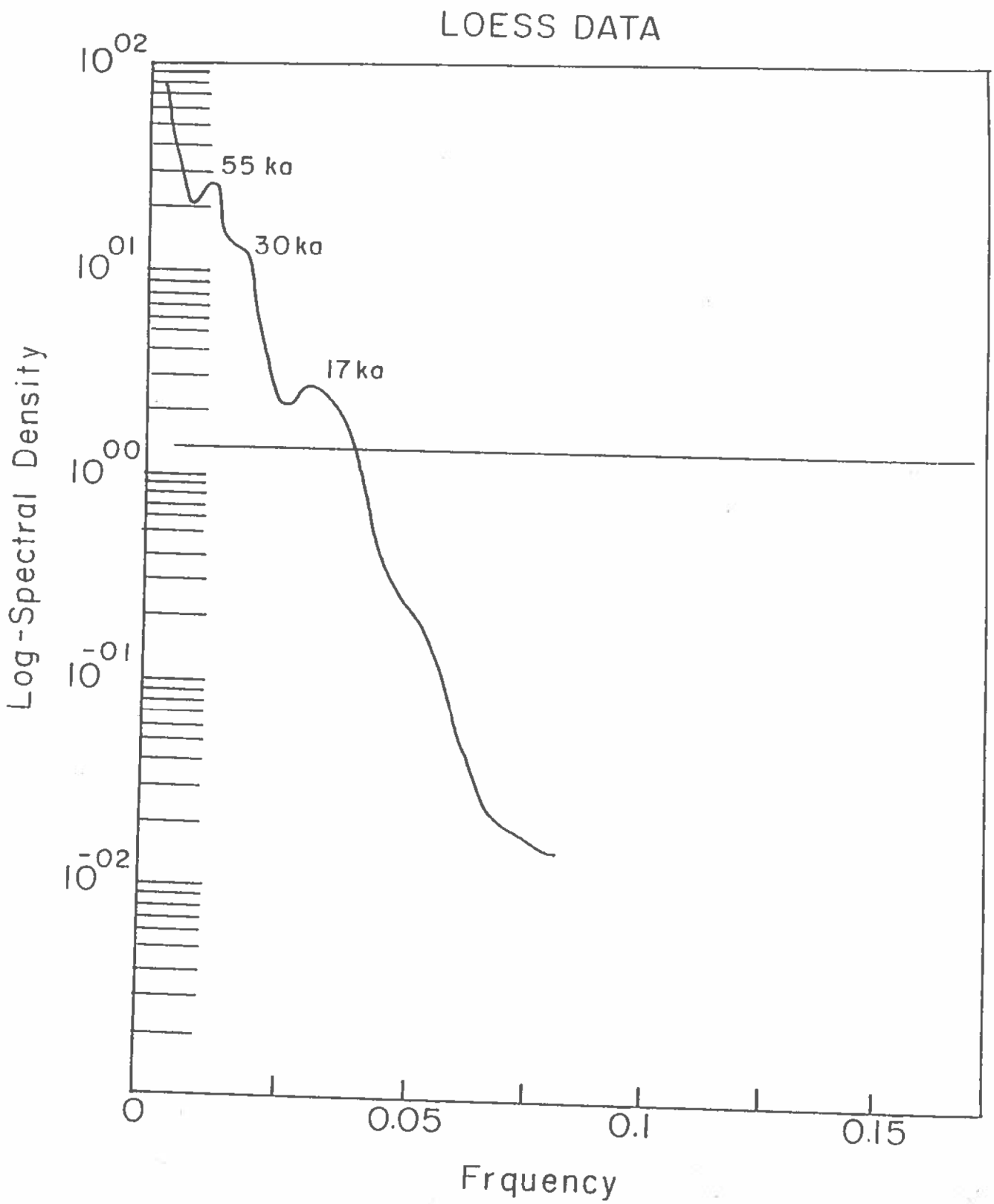


Fig. 3.1 Spectral analysis of global Loess TL dates.

simulation and geological storage it was concluded that the age under-estimation results from a combination of photo-transfer and thermal relaxation of charges in a non-radiative manner. A model has been proposed to explain the observations and to derive correction factor for the age under-estimation effect.

In the above studies extensive collaboration on geological aspect was essential. We collaborated with scientists from CAZRI (Prof. R.P. Dhir, Mr. A. Kar), from Deccan College, Pune (Drs.S.N. Rajaguru, S. Mishra, V. Gogate, M.D. Kajale), from GSI, Lucknow (Drs.B.K. Bisaria, G. Kumar, R. Kumar), from Roorkee University (Dr. B. Prakash, Mr. L.P . Singh), from Wadia Institute of Himalayan Geology (Drs.T.N. Bagati, V.C. Thakur), from University of Kiel, Germany (Dr.A. Bronger), from University of London (Drs.E. Derbyshire, R.A.Kemp), from Xian Laboratory of Loess Research, China (Dr.An Zhisheng) and from University of Aberdeen (Dr.K.W. Glennie).

(D. Banerjee, M. Someshwar Rao, N. Juyal and A.K. Singhvi)

Lake Sediments

Nal Sarovar Studies: Investigations on the 53 m long core collected from the Nal Sarovar during the summer of 1992 have been continued. As reported earlier, the recovered core comprised of three litho-units: organic mud (0-4 m); sand (4-18 m); silty clay (18-53 m); within these litho-units some variations were also seen.

Since only the topmost unit contains organic matter, studies for obtaining palaeoclimatic signatures were carried out in this unit. A series of trenches (depth 1.5 - 3.0 m) were dug at five widely separated locations within the dry bed of the Nal Sarovar to verify the continuity of this litho-unit throughout the lake bed. The base of this litho-unit has been dated by the radiocarbon method in our laboratory to be 7 ka, $\delta^{13}C$ and nitrogen were measured in the organic fraction of these sediments to obtain information on the source of carbon. As seen in **Fig. 3.2** most values of $\delta^{13}C$ of the organic matter lie between -22 ‰ to -16 ‰ (with respect to) PDB - a range that could have been obtained either from varying proportions of C_3 and C_4 type of plant debris derived from the catchment or from varying proportions of autocthonous lacustrine production and C_3 type of allocthonous input. The observation of large amount of autocthonous plant growth in the lake and their decay every year, favours the latter hypothesis. The low abundance of nitrogen probably results from the frequent (period 1-3 yrs) alteration of oxidizing (on drying) and reducing (long wet period without significant aeration) conditions of the lake during the 0-7 ka interval.

Attempts to date the lower two litho-units have not yet been successful. Radiocarbon dating of nodules yield ages > 38 ka (i.e. beyond the dating range of ^{14}C), whereas preliminary TL/OSL data do not yield concordant ages. Further, analyses are underway to test the applicability of this dating method to the Nal Sarovar sediments.

Detailed analysis of clay mineralogy has been made to infer the provenance, weathering patterns and broad climate regimes. The clay content decreases from 65 % in the top (10 - 20 cm) to 8 % at 4 m depth. Illite, chlorite, smectite and kaolinite are the major clay minerals, without any significant depth variation in relative context. Illite is the most dominant clay mineral with significant amounts of chlorite suggesting dominance of mechanical weathering (as opposed to chemical weathering) in the catchment area. The crystalinity of illite indicates an excursion towards warm and wet climatic conditions in the samples from 280 - 290 cm depth. A similar excursion has been seen in the clay mineral studies from a 12 m deep section in Ahmedabad. We are yet to chronologically correlate the events seen in the two sections.

(S.K. Bhattacharya, S.K. Gupta, Sheela Kusumgar, K. Pandarinath and Sushma Prasad)

Mansar Lake Studies: Lake sediments are a source of well preserved record of past environmental changes. As a part of ongoing palaeoclimate project, several cores were studied from the Mansar Lake, Jammu District. The lake is situated in Siwalik mountains and is influenced by south-west monsoon (**Fig. 3.3a**). To decipher the palaeomonsoon signatures contained in

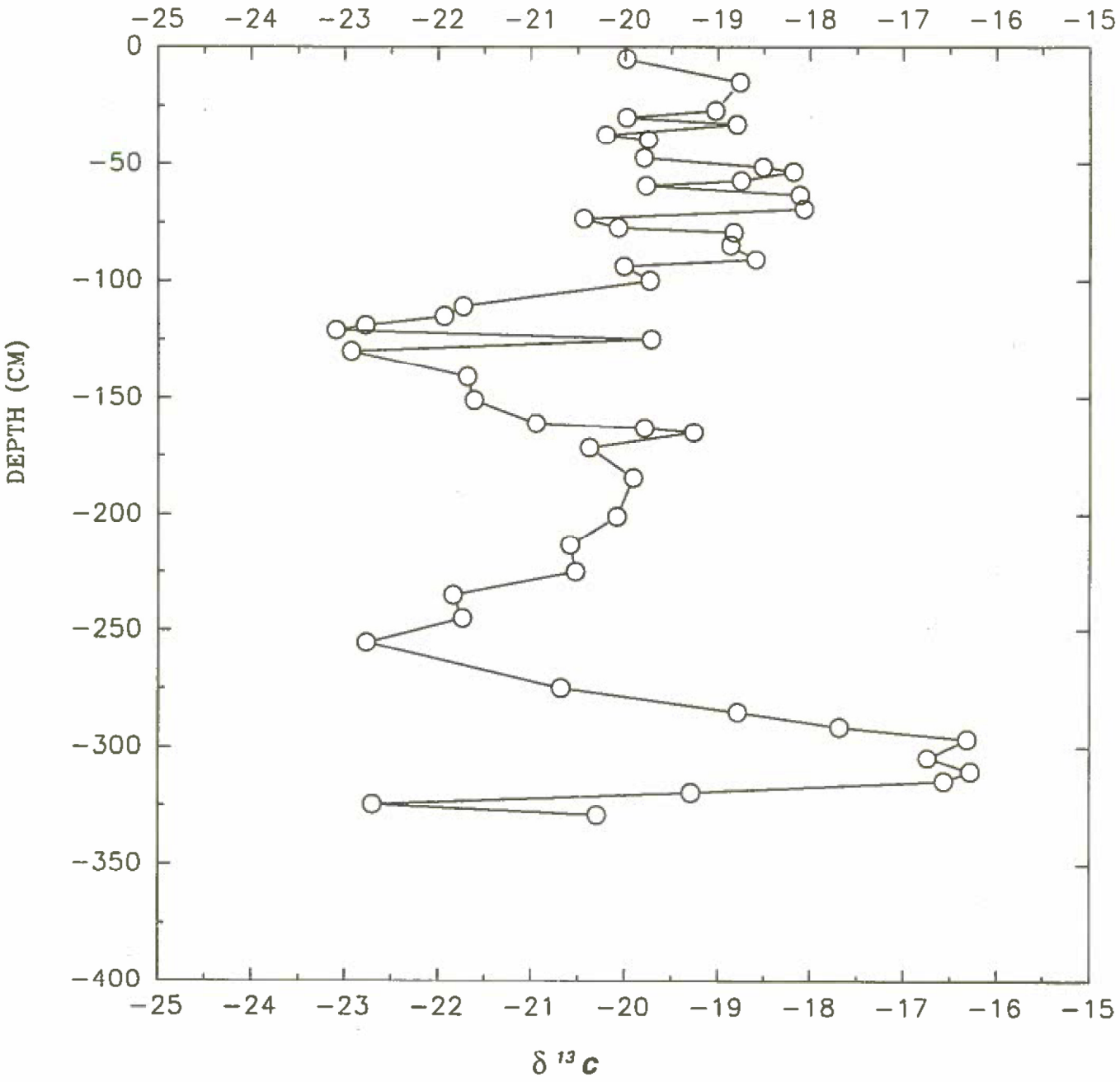


Fig. 3.2 δ ^{13}C of organic fraction in the Nal Sarovar sediment core.

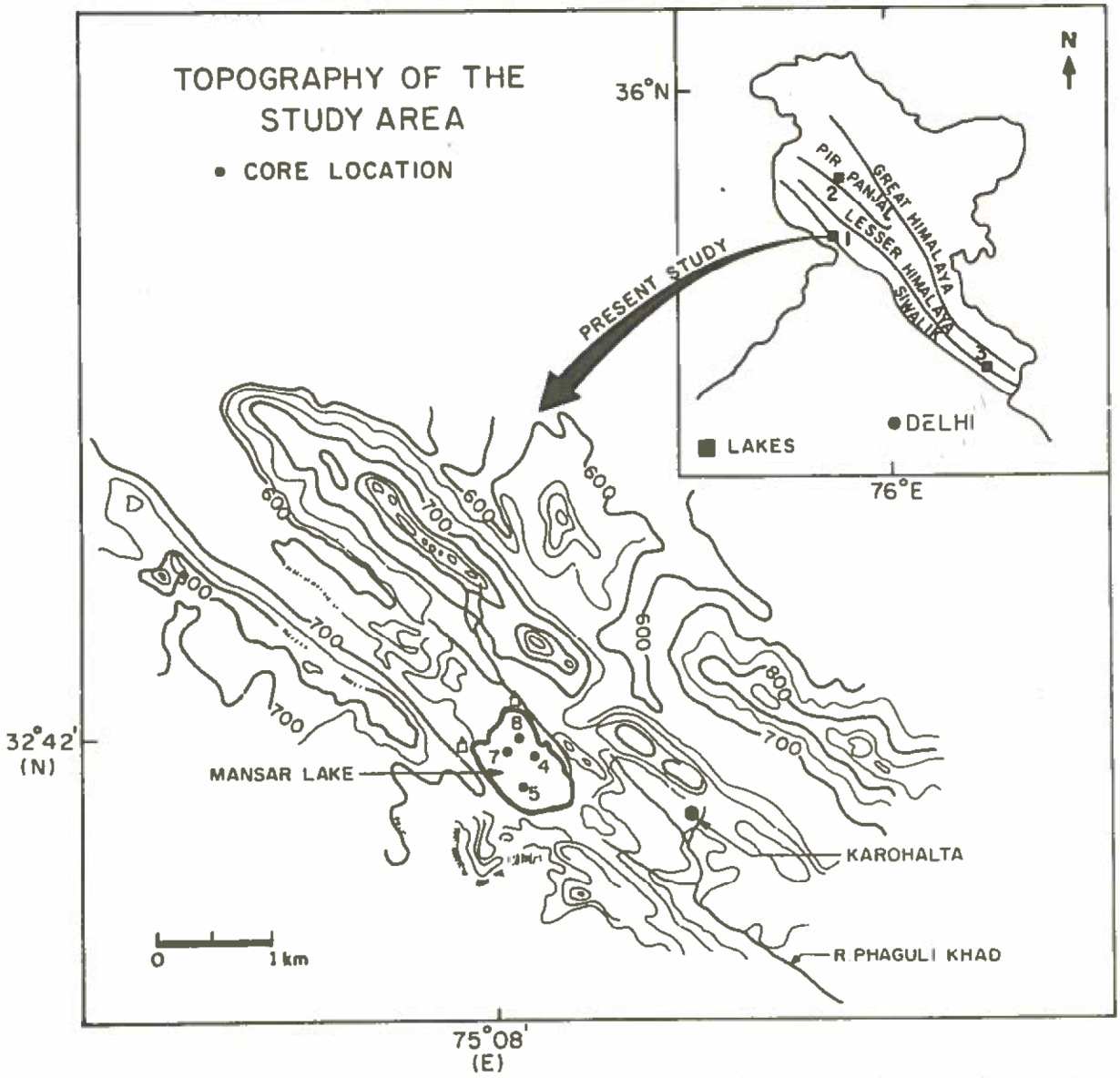


Fig. 3.3a Inset: Map of North India showing various mountain belts and locations of three different regions studied 1.Mansar Lake, Jammu Region 2.Manasbal Lake, Kashmir Region 3.Lakes in Kumaon Region
Map showing the topography of the area around Mansar Lake, Jammu region. Locations of the various cores are marked by black dots with number of the core.

these lake sediments various proxy climatic markers such as grain size (% of silt), mineral magnetics (χ_{fd}), stable isotope ($\delta^{13}C$) have been measured, ^{210}Pb and ^{14}C have been used to date the sediments (**Fig. 3.3**). The northern flank of the lake has higher sedimentation rate as compared to the southern flank (**Fig. 3.3 a,b,c**). In the absence of any major rivers and anthropogenic activities in the vicinity of the lake the variations observed in sedimentation can be correlated to changes in the precipitation regime.

The results show enhanced precipitation around 2,500 to 1,650 yrs B.P.(years before present), comparable in magnitude to the present day conditions. This

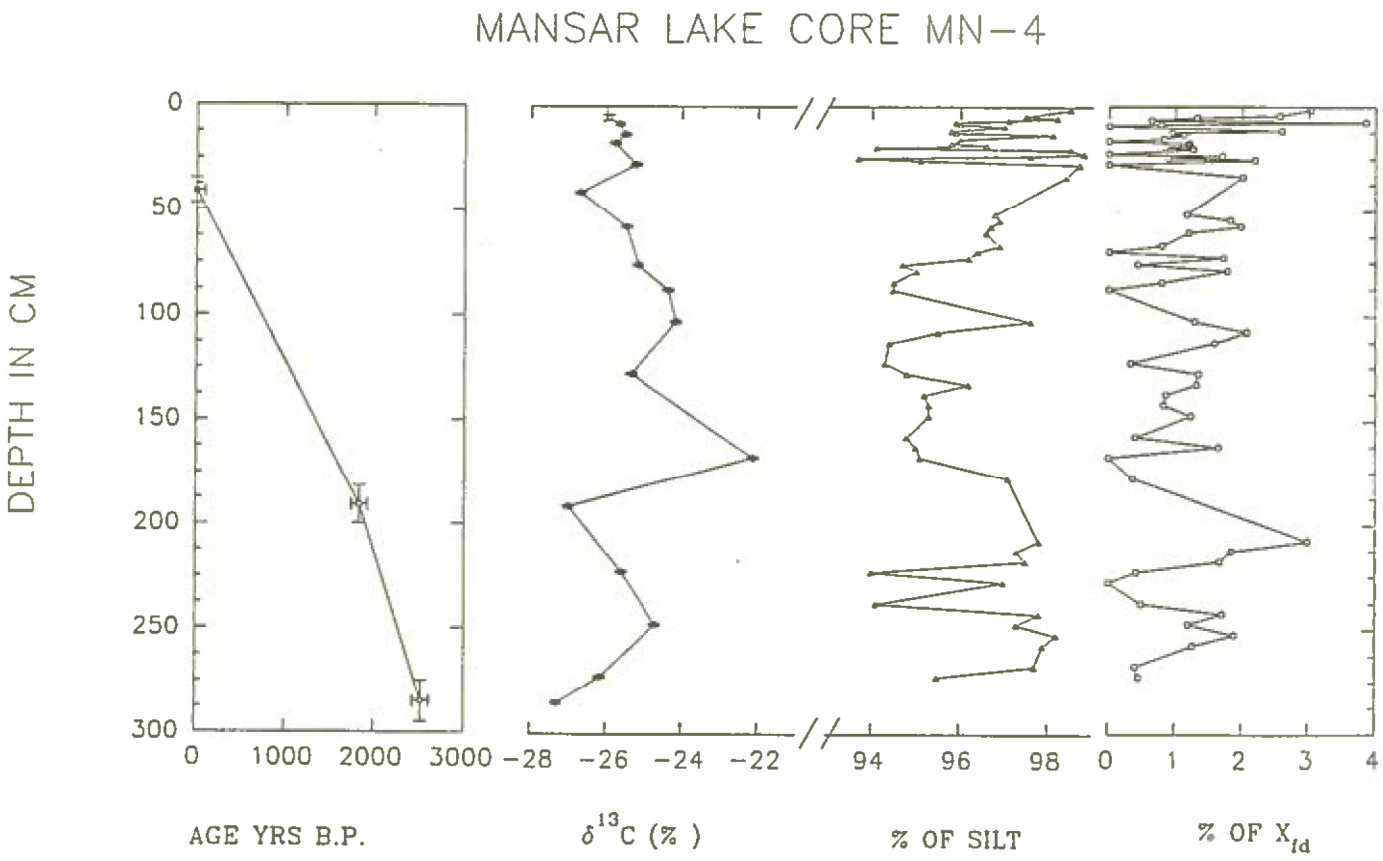


Fig 3.3b Graph showing radiocarbon age and variations in $\delta^{13}C$, percentage of silt and percentage of χ_{fd} down the core MN-4

is followed by a relatively dry and arid phase between 1,650 to 550 yrs B.P. The signature of medieval warming has been found around 900 yrs B.P. These are the first continental evidences from north-west India, suggesting that the monsoon has been fluctuating in this region through time. This work was done in collaboration with Prof. D.P. Agrawal.

(R.D. Deshpande, Sheela Kusumgar, R. Ramesh and M.G. Yadava).

Glaciers and Glacier Moraines

Glaciers are excellent high resolution repository of climate and environment. During the scientific expedition to Dokriani-Bamak Glacier, Central Himalaya, several samples of snow/surface ice, melt waters and a 6 m ice core at an altitude of 4863 m in the accumulation zone were collected. These were analysed for stable and radio isotopes ($\delta^{18}O$, ^{210}Pb and ^{137}Cs) and chemical tracers (major ions). The ^{137}Cs data in surface ice samples and in the core are used to estimate the ice flow rate of 32 m/yr near the equilibrium line; this is higher than the average flow rate of 18 m/yr reported earlier. The average snow accumulation on Dokriani Bamak glacier for the last few years has been calculated to be 0.43 m/yr. The extremely low value of $\delta^{18}O$ (-15.2 ‰) at a depth of 0.25 m in the 6 m core indicates very cold winter during 1992. These findings are supported by our chemical studies of major cations Na, K, Ca, Mg. The lower $\delta^{18}O$ value in the snout ice (-13.4 ‰) compared to that of average value of snow samples on the glacier indicates that the climatic conditions three centuries ago, during the Little Ice Age period, were much cooler than present.

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

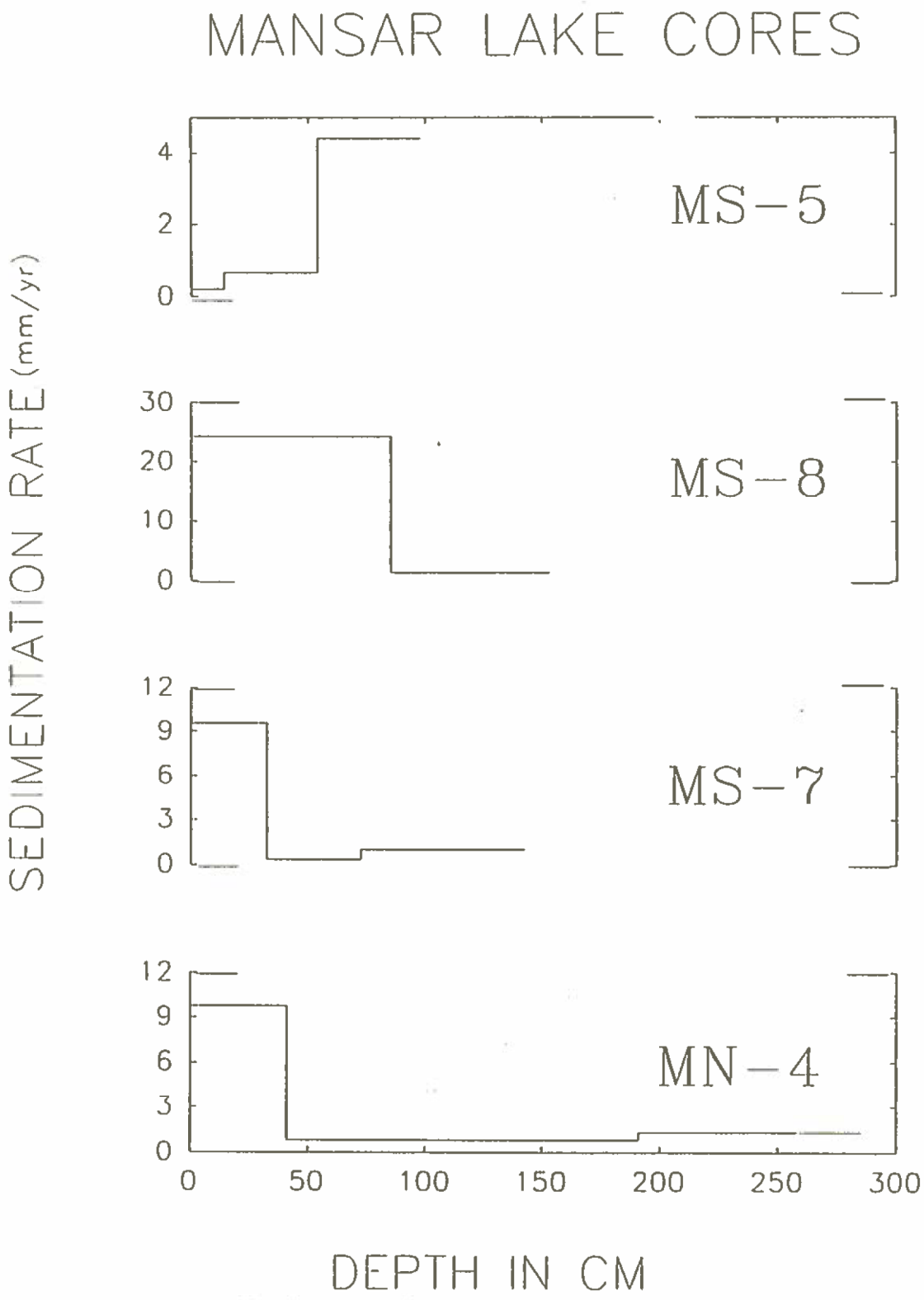


Fig. 3.3 c Graph showing variation in sedimentation rate for various cores determined by the radiocarbon method.

Quaternary Glaciation in the Central Himalaya

Documentation of Quaternary glacial extensions along the river Goriganga in the Central Himalaya north of Main Central Thrust (MCT) was completed. Field criteria such as moraine morphology, degree of cementation and compaction, clast composition, surface varnish, striations and lichens were used for relative chronology of past glacial advances. Evidences of three palaeo-equilibrium-line-altitude (ELAs) stages have been obtained. With appropriate corrections for tectonic uplift, three ELA depressions were identified as Stage-I to III corresponding to 500 m, 300 m and 200 m respectively. Stage-I is the most extensive whereas Stage-II is structured to seven sub-stages. Consideration of basin morphology suggest that changes in the ice volume varied non-linearly to the ELA depressions indicating diverse moisture regimes. Absolute dating of the moraines is being attempted using Infra Red Stimulated Luminescence (IRSL), Thermoluminescence (TL) and radiocarbon methods. A preliminary IRSL date of 2.5 ka on Stage-III moraine and a calibrated radiocarbon age of ≤ 4.2 ka on a peat sequence overlying Stage-I moraines suggests the possibility of a neoglacial advance at 2.5 ka preceded by a warmer episode at ~ 4 ka. These correlate well with the neoglacial advance in Karakorum around 2.2 ka and a warmer phase around 3.5 ka.

(N. Jyual, Sheela Kusumgar, R.K. Pant and A.K. Singhvi)

Pre-Cambrian Cambrian Boundary in the Himalaya

The Pre-Cambrian-Cambrian boundary (PC/C) interval spans a time of large scale biospheric changes, during which the major invertebrate groups appeared in the evolutionary chain. An intensive study of the transition from the relatively unfossiliferous Pre-Cambrian to the richly fossiliferous Cambrian is possible only if stratigraphically continuous suite of samples is available. Fortunately, the PC/C transition sequence constituting the Baliana, the Krol and the Tal groups in the Garhwal syncline, Lesser Himalaya, offers an excellent continuous well developed exposure. This section was taken up for a detailed study under the aegis of IGCP project 303 and the isotopic studies were carried out in PRL.

Several horizons of this two km high section have carbonate rocks which were deposited in the terminal Proterozoic sea and carry the isotopic signatures of the dissolved inorganic carbon species and sea water. About 50 samples of carbonate (whole rock) from various stratigraphic horizons were analysed to decipher the isotopic changes associated with the biospheric change for global correlation.

The oxygen isotope value of carbonates is very sensitive to post depositional changes and therefore the isotopic signature at the time of carbonate formation (corresponding to that of the original ocean water) is usually obliterated. In the present data set also, there is large variation in $\delta^{18}O$, ranging from about -14 ‰ to + 0.6 ‰. However, the mean $\delta^{18}O$ is about -6 ‰ which is close to the Proterozoic oxygen isotope value of marine carbonates.

Earlier studies of carbonate rocks have shown that the carbon isotope system is less subject to exchange during diagenesis and burial metamorphism than the oxygen isotopes. Therefore, the $\delta^{13}C$ values reflect the sea water inventory of dissolved inorganic carbon more faithfully. A plot of $\delta^{13}C$ values against the stratigraphic height in Kauriyala (**Fig. 3.4**) reveal substantial depletion of $\delta^{13}C$ at five levels in the succession.

These depletions result from the reorganisation in oceanic biomass. A detailed analysis of the results is in progress. Sampling for this work was done with the help of scientists from Geological Survey of India, Lucknow.

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

Permo-Carboniferous Sediments from Bihar: Evidence for Megamonsoon

The glaciogenic sediments of the Talchir formation, West Bokaro Gondwana basin of Bihar offers a set of samples to retrieve climatic information during the Permo-Carboniferous time. $\delta^{18}O$ and $\delta^{13}C$ measurements in the carbonate phase of these sediments show that they are characterised by extremely light oxygen isotope composition, -16 ‰ to - 35 ‰ and that $\delta^{18}O$ and

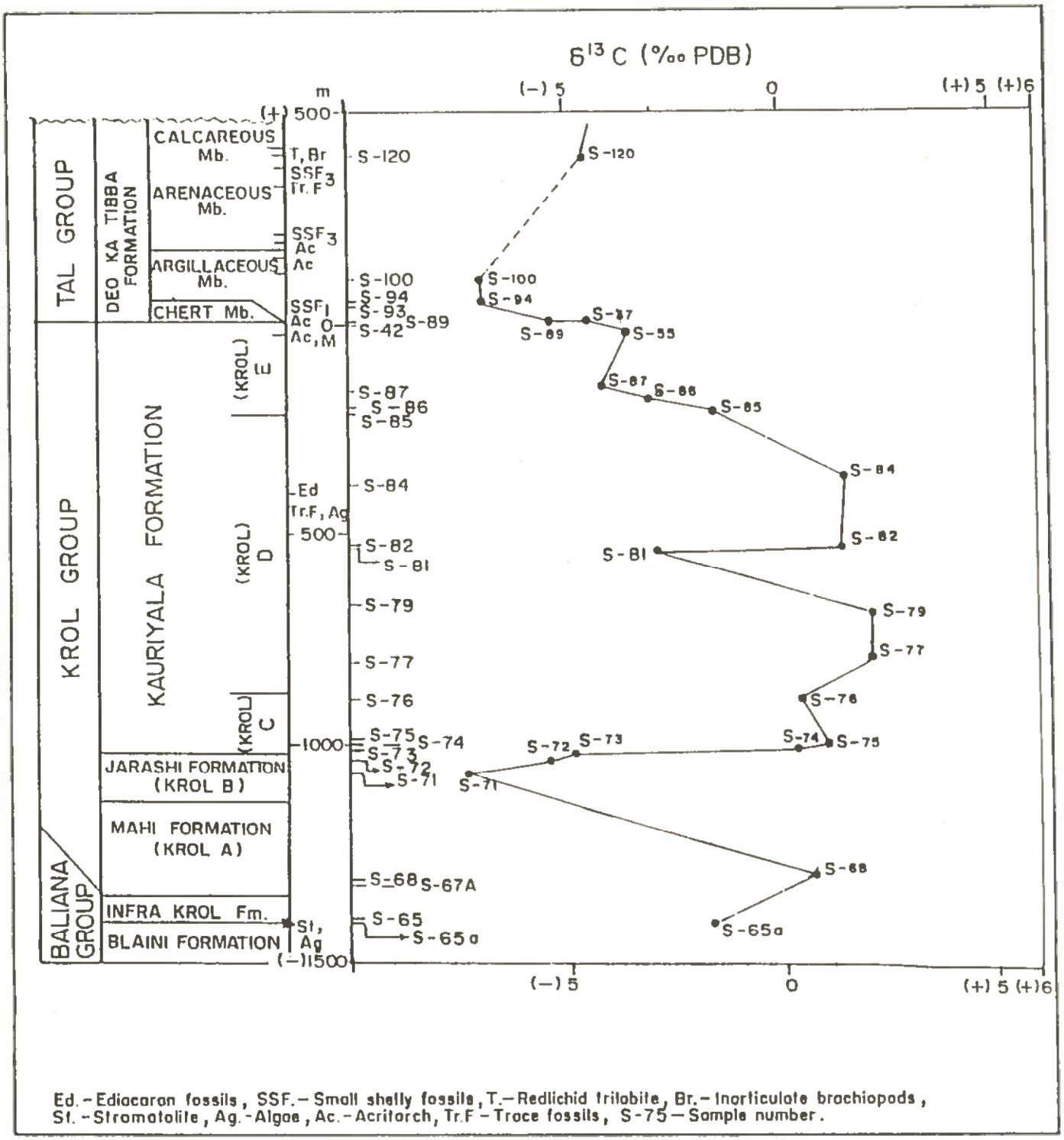


Fig.3.4 $\delta^{13}C$ carbonate excursion pattern in Baliana-Krol-Tal succession, Lesser Himalaya.

$\delta^{13}C$ are in general anticorrelated. Reported palaeomagnetic results suggest that the Bokaro basin was at about 60° S during the early Permian. If the atmospheric circulation at that time was similar to that at present, then the precipitation at Talchir is expected to have a $\delta^{18}O$ of about - 20 ‰ , much heavier than that inferred for the Talchir glacier. Another major contributing factor for the highly depleted oxygen isotope composition could be the megamonsoonal circulation during the Permian times.

Climatologists using numerical general circulation models predict that the geography of the megacontinent Pangea was conducive to the development of a megamonsoonal climate exhibiting extreme seasonality in temperature and circulation. If this circulation had been responsible for precipitation in the glaciated areas of Talchir, severe isotopic fractionation is expected as a result of large "amount effect". In addition, the models predict intense winter storms,especially near the Tethys margin in northern India. This effect also could have produced large fractionation in the winter precipitation due to extremely low temperature. The present isotopic study, therefore, offers a strong evidence for megamonsoon of the megacontinent advocated by climate analysts. This work was done in collaboration with Prof. A. Chakraborty of IIT, Kharagpur.

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

OCEANOGRAPHY

Circulation in the Bay of Bengal and the Arabian Sea

The isotope ^{228}Ra can be used to derive information on lateral and vertical mixing in the thermocline while radiocarbon content is useful to obtain estimate of deep water mixing parameters. A number of radium samples have been collected from the Arabian Sea and the Bay of Bengal and a significant part of them have been assayed for their radium isotope ratios, (^{228}Ra / ^{226}Ra) using high resolution γ - ray spectrometry. Based on analysis of about 100 samples, the ^{226}Ra and ^{228}Ra concentrations in the Bay of Bengal surface waters (lat. 10° N-20° N; long.80-87° E) are in the range of 6-11.2 dpm/100 kg and 9.2-42.1 dpm/100 kg respectively. ^{228}Ra contents as well as ^{228}Ra / ^{226}Ra activity ratios are highest in surficial waters close to the coast and decrease with distance towards the open ocean. This is expected, as the source for Ra isotopes is dissolved and desorbable components from rivers and diffusion from coastal sediments. The input of Ra isotopes to the Bay of Bengal through the seven large rivers contribute to their high concentrations. ^{228}Ra shows a linear decrease with salinity **(Fig. 3.5)** due to mixing of high ^{228}Ra fresher water with low ^{228}Ra open sea water. The lower ^{226}Ra values in the Bay of Bengal and the Arabian Sea are comparable to those reported from world oceans. These lateral and vertical profiles of ^{228}Ra / ^{226}Ra would allow the estimation of water mixing parameters, diffusion and advection.

Radionuclides in the Water Column of the Arabian Sea

As a part of the national JGOFS programme, we have measured the distributions of reactive radionuclides viz. ^{234}Th, ^{210}Po and ^{210}Pb in the dissolved phase, suspended particles and in sediment trap samples collected from the north-central Arabian Sea during April-May, 1994 and February-March, 1995. The objectives of this study are : (i) to determine the extent of radioactive disequilibrium between ^{234}Th- ^{238}U, ^{210}Po-^{210}Pb and ^{210}Pb- ^{226}Ra; (ii) to assess the relationship between the extent of disequilibrium and the rates of primary and new production, and (iii) to obtain the "effective diffusion coefficient" in the top 100 m and to place constraints on the nutrient supply to the euphotic zone from its base. The overall goal is to assess the utility of some of these disequilibria as global survey tools to determine carbon fluxes through the water column. In addition, bulk aerosol samples were collected along the cruise tracks to obtain atmospheric deposition fluxes of ^{210}Pb, NO_3 and PO_4 and to assess their role in surface water productivity.

The activity of dissolved ^{234}Th in the top 300-400 m water column is significantly less than that of its parent ^{238}U. This indicates uptake of ^{234}Th from the dissolved to particle phase with characterestic removal times of 15 - 45 days for the northern stations (> 18° N). This

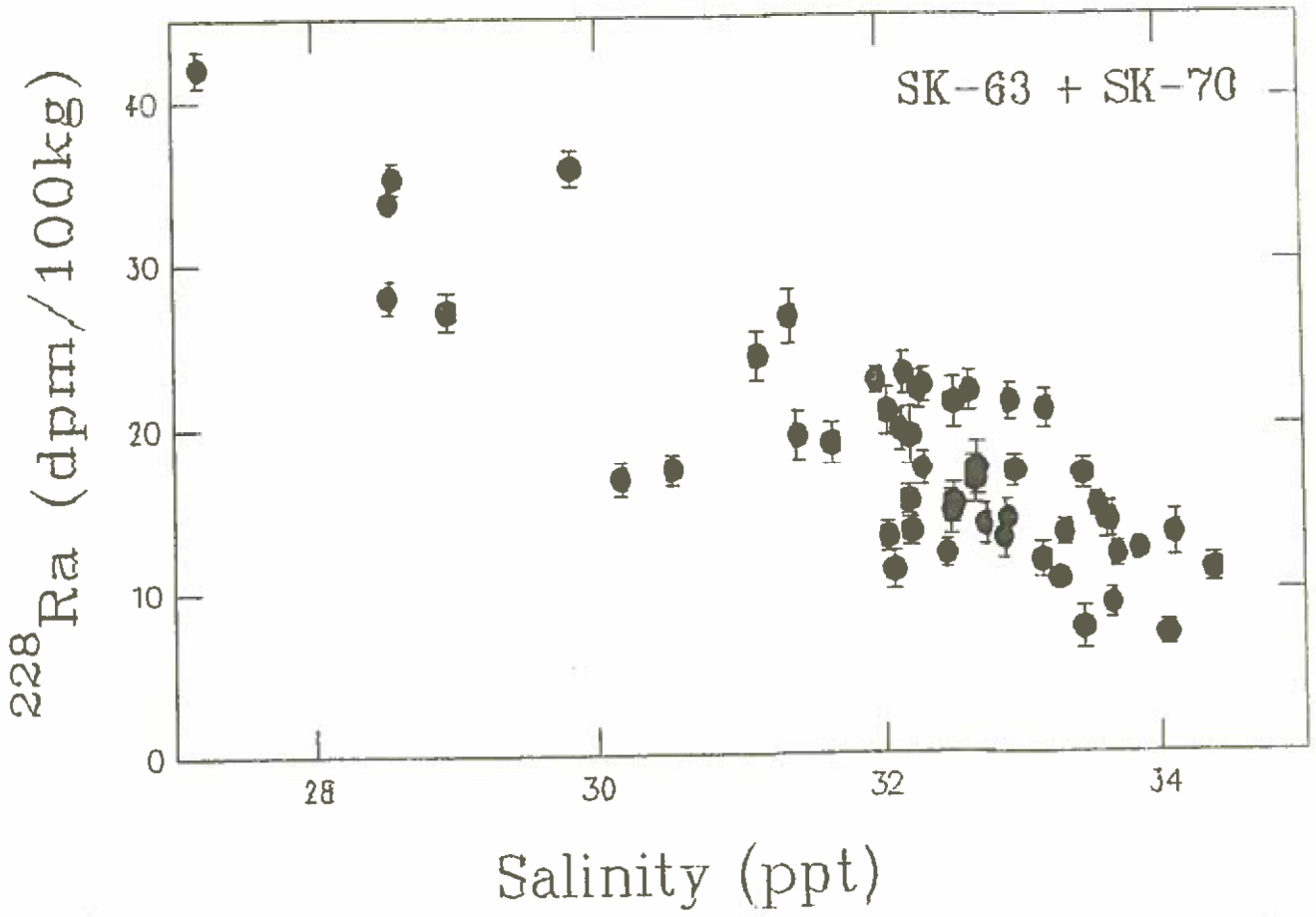


Fig. 3.5 ^{228}Ra and salinity in the water samples of Bay of Bengal.

suggests that particle associated scavenging processes are relatively pronounced in this area - a region characterised by higher rates of primary productivity. Our preliminary data does show a positive correlation between ^{234}Th scavenging rate and primary productivity that occur in the Arabian Sea.

The activity of total (dissolved + particulate) ^{210}Po also shows spatial variation with low values occurring at sites > 18° N. A distinct feature of the vertical profiles of dissolved ^{210}Po is the concentration maxima observed at ~ 100 m, suggesting that adsorbed ^{210}Po (from surface waters) is released from sinking particulate matter. Modelling of the ^{210}Po distribution in the top 100 m would help to calculate the "effective diffusion coefficient" and to constrain the fluxes of nutrients into the euphotic zone from its base.

More importantly through the measurements of water column deficiency of ^{234}Th , its flux out of the euphotic zone and the C/ ^{234}Th ratio in the settling particles (based on analysis of sediment trap samples) it should be possible to provide quantitative estimates of carbon fluxes out of the euphotic zone.These studies are in progress.

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

LIMNOLOGY, HYDROLOGY AND WEATHERING

Chemical and Isotopic Evolution of the Sambhar Lake Brines

A detailed study of chemical and isotopic composition of the Sambhar lake waters during its annual wetting and drying cycles have been carried out to infer

the chemical and isotopic evolution of the brines and the source of salt to the lake.

The $\delta^{18}O$ value of the lake waters during October, overlaps with that of local precipitation (-6.4 to -3.2 ‰) suggesting that the recharge is dominated by atmospheric precipitation. This value steadily increases and reaches a plateau at + 21 ‰ during summer. The annual evolution of oxygen isotope composition in the lake waters is of Rayleigh type and model calculations suggest that isotopically light atmospheric water vapour with $\delta^{18}O$ of about -20 ‰ controls the evolution trend through back condensation during pre-and-post monsoon months.

The concentration of NaCl in the lake water during October is ~ 9 g/l, significantly higher than that in local rain water, ~ 0.002 g/l and river water ~ 1 g/l . Material balance calculations suggest that less than 5% of the salt in the lake is derived from rainfall and surface runoff, while the bulk is from the redissolution of halite crusts formed on the lake bed during summer by the evaporation of lake water.The strong correlation between U-TDS and the constant $^{234}U / ^{238}U$ activity ratios during the entire annual cycle also precludes significant supply of NaCl (associated with uranium) by marine aerosols from the Rann of Kutch.

Modelling the chemical evolution of the brine following the Hardie-Eugster concepts suggests that evaporation of pure river and ground waters from the region cannot produce the observed composition of the lake brine. Addition of NaCl to these end members and the evaporation of the mixture yield brines having chemistry closer to that in the lake. This is consistent with the earlier inference that redissolution of halite from the lake bed contributes significantly to the present day NaCl abundance in the lake.

(S. Krishnaswami, R. Ramesh, M.M.Sarin and D.N. Yadav)

Water Budget of Monsoon Rainfall : Role of Evapotranspiration.

The estimation of moisture sources of rainfall and its partitioning into various components indicate that there is a significant excess of precipitated water compared to primary moisture flux from the ocean (the Arabian sea or the Bay of Bengal). An independent approach to check this is through the study of isotopic composition of rainfall and its spatial distribution. The isotopic composition of rainfall is dependent on (i) isotopic composition of the primary source; (ii) inland modification due to rain out and mixing of evapotranspiration component; (iii) temperature of condensation. Due to the scarcity of data on isotopic composition of rainfall we proceed by assuming that the shallow ground water at any given place isotopically represents long term average of rainwater.

We have collected about 200 water samples along the track Ahmedabad to Kanyakumari in the post monsoon season of 1994. In this sector orographic, amount and selection effects are expected to play important roles in isotopic characterisation of rain, soil moisture and ground water. In order to analyse these samples rapidly, we are currently enhancing our sample handling capacity by modifying our sample loading and extraction line and the equilibration system. The isotopic data will help us in understanding the mechanism of the rain out process and the effect of orography on the amount of rainfall.

We are also measuring the isotopic composition of the soil carbonates collected at several places along the same route. This will help in generating a data base relating the water composition and the pedogenic carbonate composition which can be used in future palaeoclimatic research.

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

Storm Water Drainage and Groundwater Recharge in Ahmedabad

Feasibility of shallow depth ground water recharge of storm water as a means of affecting storm water drainage and as a water conservation measure was examined through a set of experiments at Ahmedabad. The results though encouraging, yielded recharge rates too low (5-20 litres/min).

To overcome these problems, it was decided (i) to increase the percolation area of the aquifer being recharged and, (ii) to provide a temporary underground storage for the large amount of runoff. Based on these considerations, a percolation well, in many ways similar to a conventional soak pit, was designed and constructed in Maninagar, Ahmedabad. This well had a catchment area of ~ 1500 m^2. Though the 1994 monsoon in Ahmedabad was heavy, with at least 3 spells having more than 10 cm rainfall in 24 hrs, the percolation well did not overflow and the collected water was dissipated within about 96 hours. The system resulted in a ground water recharge of about 1800 m^3 during the entire monsoon season. This idea is now being extended to other areas of Ahmedabad with support from local Government agencies.This programme is done jointly with Mayur Shah, A.S. Chaturvedi and D.R. Shah.

(S.K. Gupta and P. Sharma)

Water Renovation through Soil-Aquifer-Treatment using Sabarmati River Bed.

The soil-aquifer-treatment (SAT) involving percolation and filtration of waste water through unsaturated soil zone and polishing treatment through aquifer traversal can provide a cost effective renovation method of waste water. A pilot project based on this concept is being done jointly with the National Environmental Engineering Research Institute (NEERI) and Ahmedabad Municipal Corporation (AMC) in the Sabarmati river bed near the Vasna Sewage Treatment Plant. As part of this project, two infiltration basins having two pumping and four observation wells have been constructed. The two pumps together have now been pumping water at the rate of 0.35 million gallons per day of bacteria free drinking quality water for over a month. The preliminary results are encouraging and detailed studies are underway to operationalise the system for optimum quantity/ quality of water renovation.

With a view to study the processes operating during renovation of waste water in the SAT method, a lysimeter experiment has been set up in the campus of the Vasana Sewage Treatment Plant. The permeability of the sediment in the sand column under saturated flow conditions has been estimated to be about 10m/day. Further, the response of the sand column to a pulse of NaCl tracer has been studied. **Fig. 3.6** shows the 'breakthrough' curve of the tracer. Such breakthrough curves are also being obtained for other constituents to estimate the attenuation of these constituents through adsorption/ exchange with the material of the sand column. This project is being carried in collaboration with Mr. P. Nema of NEERI.

(S.K. Gupta and P. Sharma)

Sr Isotopes in Rivers of India and Pakistan

This is a part of our geochemical reconnaissance study of rivers from the Indian sub-continent. We have earlier highlighted the Sr and U-isotope data from the three Himalayan river systems - the Ganga, Brahmaputra and Indus. We have now measured the dissolved Sr concentration and $^{87}Sr/^{86}Sr$ of the major Peninsular rivers to obtain data on the flux of Sr isotopes transported by these rivers from the sub-continent to the ocean and their impact on the Sr isotope evolution of the ocean. Further, as the river basins comprise a diverse set of lithologic, tectonic and climatic regimes, they provide an opportunity to study the controls these factors place in determining the Sr isotope systematics of rivers.

The data indicate that the Sr concentration in the Peninsular rivers ranges between 180 and 5199 nmol per litre, similar to the observed values from other parts of the world. The Sr concentration shows a general increase with Ca. The Sr/Ca molar ratio of the peninsular and the Himalayan rivers overlaps within the scatter of the data. The mean molar Sr/Ca ratio corresponds to a Sr/Ca weight ratio (g/g) of 7×10^{-3} for the Peninsular rivers. The $^{87}Sr/^{86}Sr$ ratios of these rivers fall within a narrow range of 0.71 to 0.72 and are generally lower than the $^{87}Sr/^{86}Sr$ of the Himalayan rivers. The contrast is much more pronounced when $^{87}Sr/^{86}Sr$ of the Peninsular rivers are compared with those for the head waters of the Ganga and Ghaghara. The $^{87}Sr/^{86}Sr$ of the Peninsular rivers and those reported by us for the Ganga, Brahmaputra and the Indus yield a discharge weighted mean Sr concentration of 1.4 µmole/litre with a $^{87}Sr/^{86}Sr$

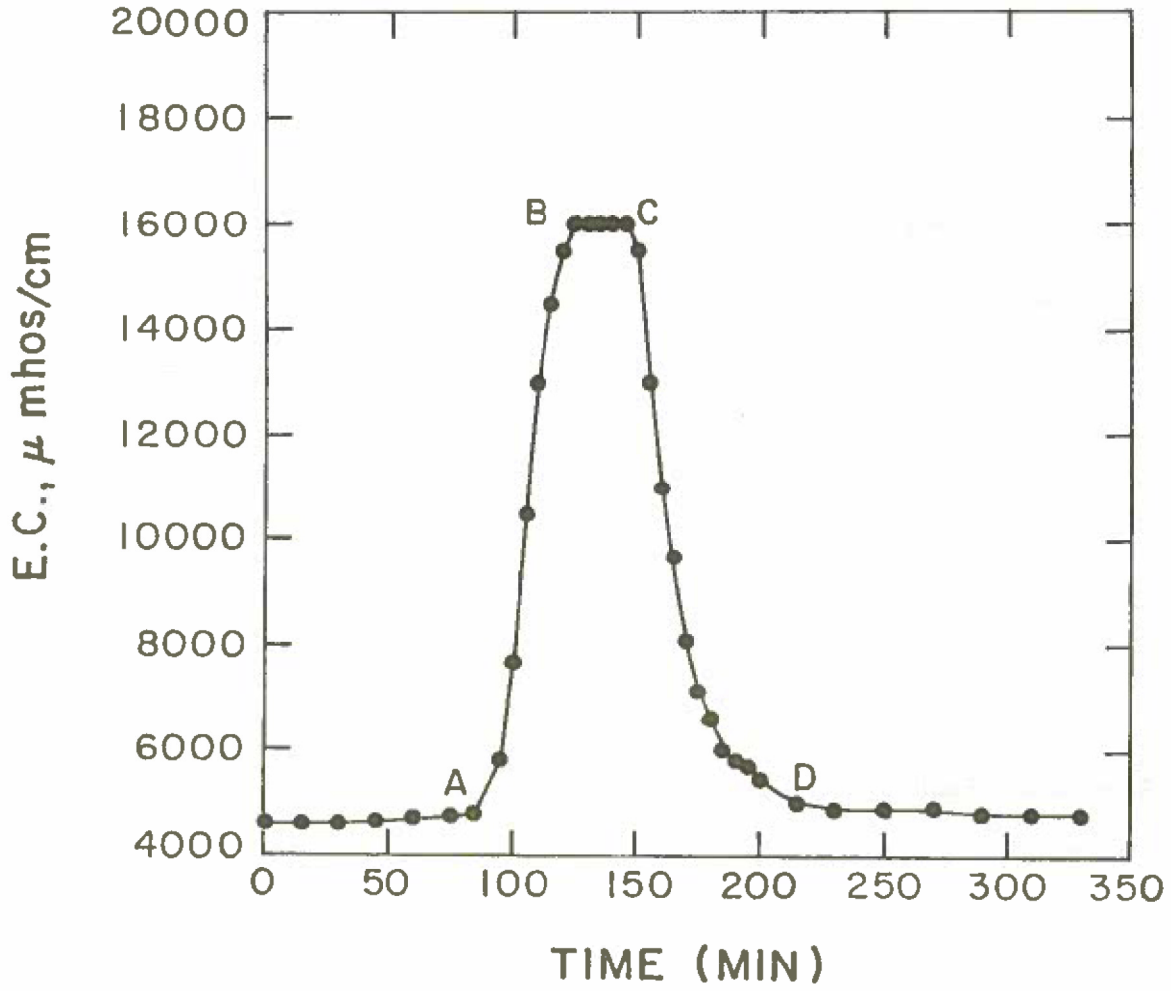


Fig. 3.6 Breakthrough and elution curve of NaCl tracer solution in the sand column of lysimeter. The tracer injection started at t =0 and the first arrival was detected at 'A'. At 'B' the output tracer concentration was equal to the input tracer concentration. The section CD represents the elution of the column. The EC returned to the background at the point 'D'.

of 0.716. This mean is higher than the global average value of 0.89 μmole/litre. The annual flux of Sr transported by rivers from India and Pakistan to the ocean is ~ 2150 million moles. These calculations show that the rivers from the Indian sub-continent account for ~ 6.5% of the global riverine flux to the ocean with $^{87}Sr/^{86}Sr$ marginally more radiogenic than the global average.

(S. Krishnaswami, K. Pande, M.M. Sarin and J.R. Trivedi)

Stable Isotope Studies of Carbonatites

Most of the carbonates found on the surface of the earth are of marine origin. There is a special type of carbonate, which is not of marine origin, but is igneous. The study of such igneous carbonates, called carbonatites, provides clues to the rock forming processes that take place in the upper mantle. Last year a programme was initiated to study the stable isotope composition of carbon and oxygen in carbonatite rocks of India. In this context, a model to study Rayleigh isotopic fractionation in multicomponent systems, such as carbonatites, was developed last year. A number of samples from one of the largest Indian carbonatite bodies, namely, Ambadongar, located in Baroda District, have been collected and analysed for their C

and O isotope systematics. This body had been earlier well studied by the Indian petrologists. Analysis of these rocks revealed two generations of magma flow in this body, with distinctly different source compositions, consistent with the conjecture made by petrologists based on grain size observations. **Fig. 3.7** shows the plot of $\delta^{13}C$ versus $\delta^{18}O$ in the Ambadongar carbonatites. Except for the two heavily altered values in the right-top corner, most of the values fall along two curves. Curve-I fits our model when the temperature is assumed to be 700° C and the molar ratio of H_2O/CO_2 to be 0.5. Curve-II, which is composed of fine grained carbonatites, also fits the model with 700° C and H_2O/CO_2 of 0.5, but with a distinctly different initial isotopic composition. The most probable reason for this is that mantle does not have a unique isotopic composition, but is heterogeneous. Dating of these two generations of carbonatites is in progress.

(R. Ramesh and J.S. Ray)

National Radiocarbon Facility

The radiocarbon laboratory continues to assist various programmes in the Universities/Research Institutes by providing chronology for their archaeological and geological samples. Some of the important samples dated by the radiocarbon laboratory last year and their implications are given below.

The first precise age for the iron age culture from Maharashtra, which have been obtained from various habitational levels from the Megalithic site "Adam" has been determined to lie between 2 to 4 ka B.P. A similar chronological framework between 3 to 4 ka B.P. is assigned to a chalcolithic site in Maharashtra "Loteshwar". This site has shown various artefacts and human skeleton remains. In Udaipur an early historic site at Balthal has shown different occupational levels associated with copper, bronze, iron tools etc. The earliest phase dates back to 4 ka B.P. and terminates at 2 ka B.P.

The coastal Saurashtra is considered to be ideal location along the west coast of India for sea-level studies. There are various evidences of past high sea stands along the coast. Oyster reef is one such evidence which suggested that sea level has receded to the present level in the geological past. The dating of oysters can help in ascertaining the time of different high sea-level which can in turn present evidences in local and regional perspectives. In continuation of our programmes on sea-level variations, oysters from Devka river (20° 59' N, 70° 21') were dated and their ages centre around 27 ka B.P. Since the oysters grow insitu, it implies that the sea-level was higher compared to the present level during the above time. In the absence of geochemical data this could be taken as the minimum age.

(Sheela Kusumgar and M.G. Yadava)

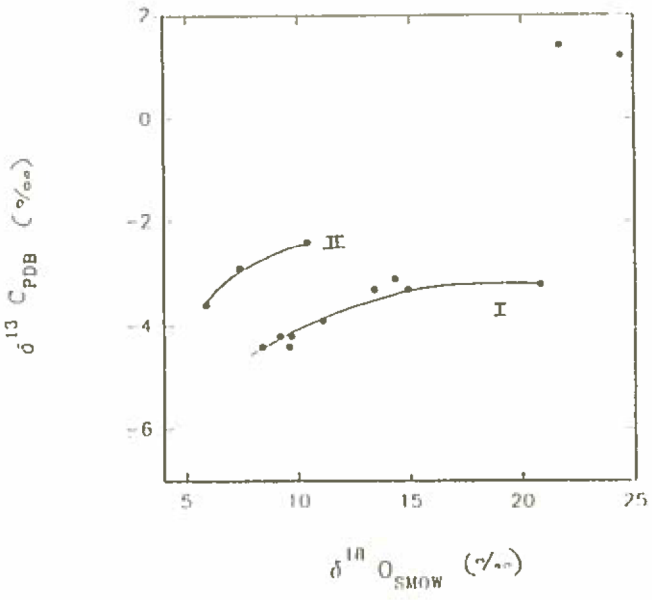


Fig. 3.7 The carbon and oxygen isotopic composition of Ambadongar Carbonatites. They show two distinct isotopic evolutionary trends (curve I and curve II) indicating two different generations of carbonatites with different isotopic ratios. See text for detailed explanations.

SOLAR SYSTEM AND GEOCHRONOLOGY

Multiple Events at the Cretaceous Tertiary Boundary

Sixty five million years ago, the Earth went through one of the most dramatic phases in its geologic history. The climate drastically changed, a large fraction of living species on the Earth died as a consequence of severe stress caused by receding sea levels, drastic changes in temperature and a huge volcanic eruption in Central India. The initial cause and the consequent physio-chemical events leading to these changes form one of the important subjects of studies at present. Whether the large scale volcanism in Deccan itself was the cause or a large bolide hit the Earth at that time are the two competing hypotheses proposed to explain the series of sudden events that took place at this time.

The identification of a site at Anjar in Kutch by our group where these records are preserved in the sedimentary layers was made about a year ago. The Anjar trap sequence consists of seven basalt flows, several of them contain well-developed thick (10-15 m) intertrappean beds. The intertrappeans consist of shale, limestone sequence and dinosaur fossils have been reported from II and III intertrappean beds. We found a clay layer rich in the diagnostic element iridium capping the uppermost dinosaur fossils, accompanied by anomalously high concentration of certain chalcophile elements e.g. Se, As, Zn, Sb and Ag in the third intertrappean at Anjar. This intertrappean bed had a large sedimentation rate providing a very high resolution sequence stratigraphy of events that occurred at that time. We have now carried out a detailed geochronological, geochemical, palaeomagnetic and paleontological study of this section. The field work related to this study has been carried out in collaboration with the Geological Survey of India.

Geochronological Framework

The seven lava flows at Anjar were dated by ^{40}Ar-^{39}Ar method. It has been found that the seven flows encompass a time bracket of 68.7±0.4 to 61.0±0.8 Ma (**Fig. 3.8**). The flows III & IV which sandwich the K/T boundary give a value close to 65 Ma. (F- III = 65.3 ± 0.3 Ma).

These data indicate that the Deccan volcanism was active about 3 Ma before the K/T event and continued for about 4 Ma thereafter. The ages of the flows confirm our earlier conclusions that the impact did not trigger Deccan volcanism and the initial surge of Deccan volcanism predate K/T event by nearly 3 Ma.

Magnetic Polarity of Flows

In order to provide an independent time frame, polarity of various flows at Anjar were measured using a spinner magnetometer. It appears that the secondary component in all the flows is significant masking the original polarity. The lower three flows show a normal polarity whereas the upper three flows show a reversed polarity. The polarity of flow IV could not be measured with confidence because of erratic behaviour of the basalt and poor statistics. The results thus indicate that the Anjar basalts show a N-R polarity sequence.

Geochemical Stratigraphy

A more detailed chemical stratigraphy was constructed with a high time resolution. The study shows presence of three horizons rich in iridium, osmium and chalcophiles, separated by about a foot within the third intertrappean bed (**Fig. 3.9**). Each iridium rich horizon is immediately followed by a white layer. The chemical study of this white layer is in progress now.

Presence of three well separated iridium rich horizons reopens the question of multiple events at the K/T boundary. These events could have been compressed into one in the marine sections because of their very low sedimentation rate. The study brings out the importance of Anjar section in providing a high time resolution event sequence, which may enable us to understand the K/T event in detail. It may be noted here that an asteroidal impact should lead to a single iridium-rich horizon whereas only a cometary shower can give rise to multiple horizons as seen at Anjar. A model is being developed to take into account the geochemical and geochronological data.

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

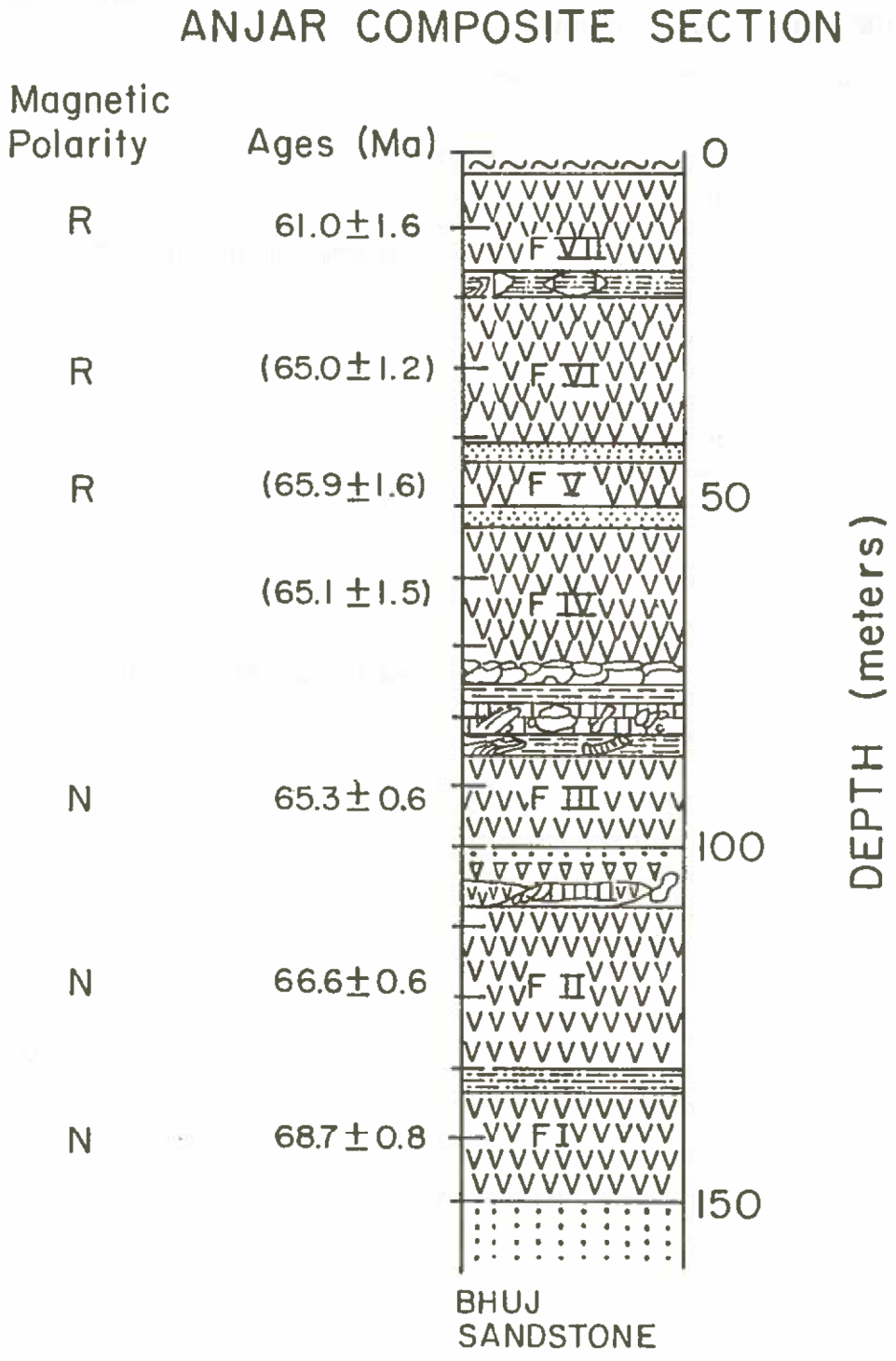


Fig. 3.8 Magnetic polarity and ^{40}Ar-^{39}Ar ages for various Anjar flows are shown on the composite section. The plateau ages are given for flow I, II, III and VII. The ages within parenthesis are integrated ages. The errors on ages are 2σ.

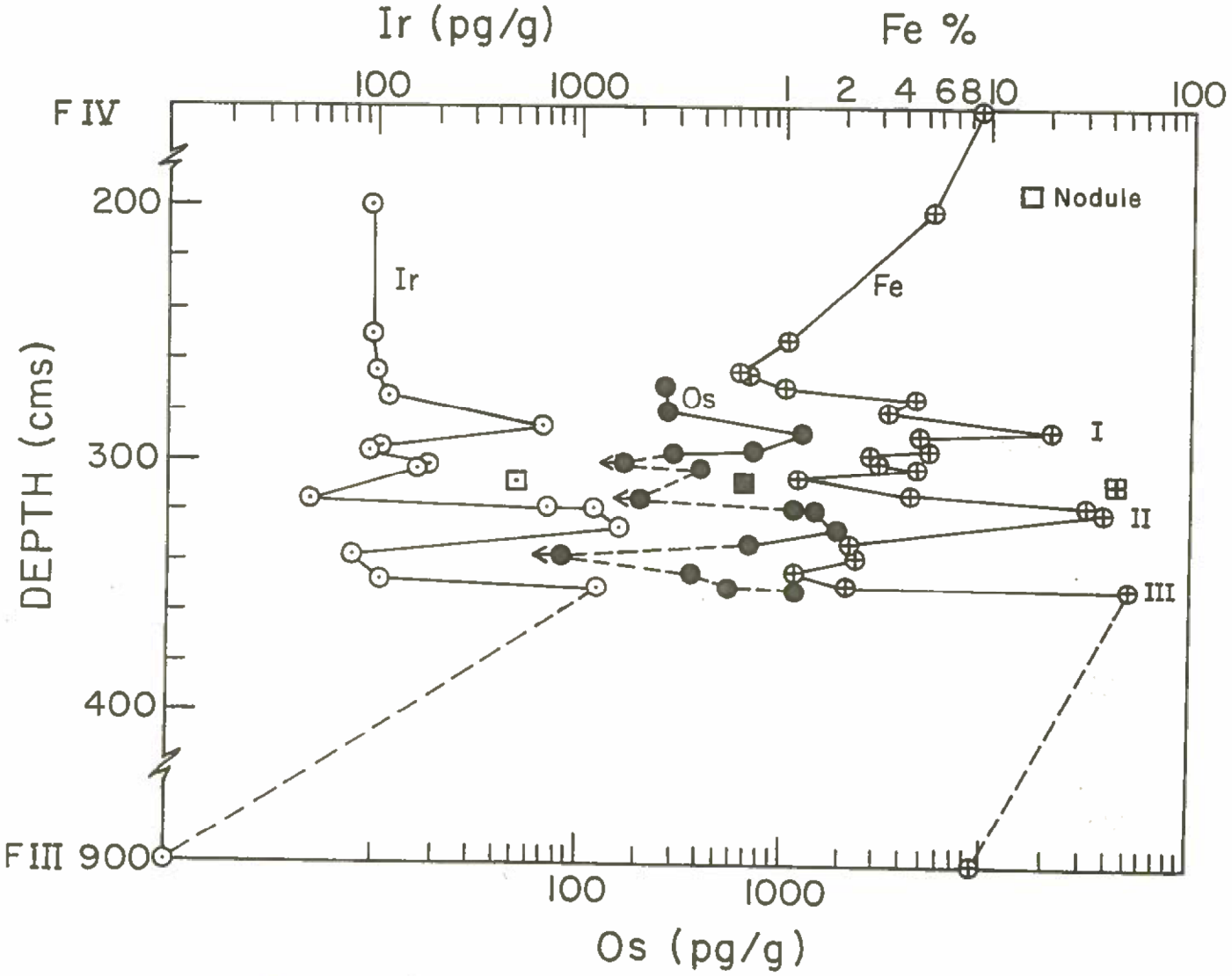


Fig. 3.9 Depth profiles of Ir, Os and Fe in Flow III of Anjar intertrappean section. The depth is measured from the base of Flow IV. I, II, III are the three limonitic layers, patchy but continuously traceable along the horizon. A confined limonitic nodule (2cm diameter) rich in Ir, Os and Fe was also located and its data points are circled.

$^{207}Pb/^{206}Pb$ Dating of Single Zircons by the Ion Probe

We have continued our geochronological studies of the Rajasthan Aravallis and have also initiated studies of samples from the Singhbhum (Orissa) iron-ore craton using the Pb-isotopic dating of single zircon by the ion-probe.

Age of the Amet Granite, Rajasthan

The Amet Granite is located on the periphery of the Sand Mata granulite complex in central Rajasthan. At the sampling site, this granite consists of a homogeneous, mesocratic gneiss containing cm-sized feldspar augen. Numerous leucocratic dykes are present which clearly cross-cut the foliation of the host augen gneiss. Field evidence suggest a distinct geometric and possible genetic relationship between the augen gneisses and the granulite complex. We have dated zircons from a sample of strongly foliated augen gneiss and a leucocratic dyke which cross-cuts the foliation. An age of 1641±14 Ma (million annum) was obtained for the Amet granite which rules out an Archean antiquity for this rock

unit, as proposed in some earlier studies. Our data combined with field evidence suggest that granulite facies metamorphism in Sand Mata complex took place in mid-proterozoic. Our work also shows that accurate background correction is essential while estimating ages of young zircon (< 2 Ga), where the ^{204}Pb count-rate is close to the background level. The use of small geometry ion microprobe, such as Cameca Ims-4f, for obtaining zircon ages is therefore best suited for older and radiogenic and Pb-rich samples.

(J.N. Goswami and M. Wiedenbeck)

Oldest Crustal Component of the Indian Shield

The Singhbhum (Orissa) iron-ore craton of Eastern India is a crustal block of Precambrian age covering an area of 40,000 sq. km. Geological considerations suggest this craton to be one of the oldest crustal block in the Indian shield that has recorded a continuous geological history from about 4.0 to 1.0 Ga. Although extensive petrological and geochemical studies of this crustal block have been carried out over the years, a proper geochronological framework is still lacking. We have therefore initiated a program to carry out geochronological study of some of the important rock units of this batholith using the ion-probe zircon dating approach. A field expedition was conducted during early 1994 and samples from five rock-units, that appears to have certain chronological relation (based on field evidence) were collected for this study.

The most significant result obtained so far is the discovery of 3.56 Ga old zircon in metasediments, the oldest unit of this craton that can be identified in the field (**Fig. 3.10**). This age provides an upper limit for the age of the sediments and also constrain the time of onset of the evolution of this crustal block. This is the oldest age for any crustal component reported within the Indian shield. Our zircon data also showed that the oldest igneous rocks in this craton have ages of ~ 3.4 Ga. The older age of 3.8 Ga reported for this rock unit from earlier studies appear erroneous.

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

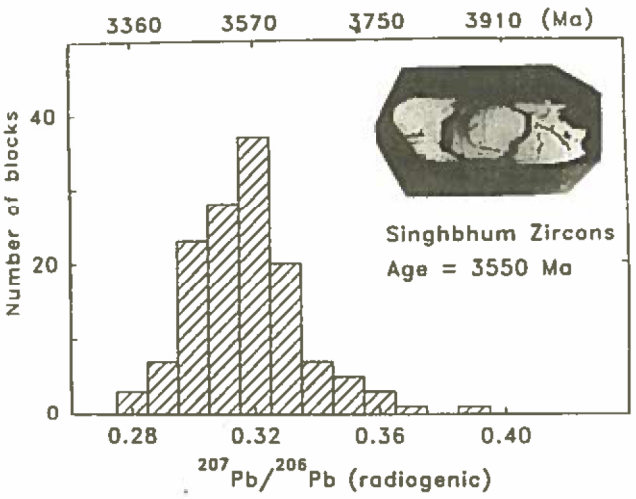


Fig.3.10 $^{207}Pb/^{206}Pb$ ratios measured in zircon grains from Singbhum region that yielded an age of 3.56 Ga. The inset shows a zircon with a distinct rounded core that belongs to this age group.

Origin of the Solar System and Evolution of Meteorites

The carbonaceous chondrites represent some of the most primitive objects in the solar system. In particular, these meteorites contain some rare and extremely small inclusions, the so called Calcium-Aluminium-rich Inclusions (CAI), enriched in refractory elements (Al, Ca, Ti, Mg, etc.) that are considered to be some of the first solids to form in the solar system. Isotopic studies of these small objects, continue to provide new information about formative stages of planetary bodies. In addition to the CAIs, there are other objects in meteorites, that also appear to have formed during the very early history of the solar system and can provide information complementary to those obtained from CAIs. We have used the ion microprobe to study isotopic composition of some such rare phases to check the validity of certain hypotheses proposed on the basis of studies of mineralogy and mineral chemistry of these objects.

In addition, analysis of the bulk material of meteorite also provide some interesting clues about the

environment and processes during the formation of the meteorite parent bodies. We have used mass-spectrometric methods to study isotopic composition of nitrogen and noble gases in some specific meteorite samples to address the question of the isotopic composition of nitrogen in the solar nebula at the time of formation of these objects.

Although asteroids are the major sources of meteorites, we now have specimens of meteorites that are fragments of Moon and Mars. A detailed study of a martian meteorite recovered in Antarctica was carried out to obtain information about its cosmogenic records and also to derive its age, time of its ejection from Mars, the Mars-Earth transit time and finally atmospheric ablation suffered by it. In the following we provide a brief outline of the important results obtained from the above studies.

Observation of Correlated ^{26}Al and ^{41}Ca in Early Solar System Objects

The evidence for the presence of the short-lived $^{41}Ca(\tau = 0.15$ Ma) in the early solar system, reported by us last year, has constrained the time scale for the collapse of the molecular cloud fragment to form the sun and the first solar system solids to < 1 Ma. During the current year, we have carried out further studies of additional samples of CAIs from the Efremovka meteorite to consolidate our earlier findings. The new results obtained by us confirm the presence of ^{41}Ca in the early solar system. The enlarged data-base define a more precise initial $^{41}Ca / ^{40}Ca$ of $(1.4\pm0.2) \times 10^{-8}$ at the time of formation of Efremovka CAIs. This is consistent with the initial value of $(1.5 \pm 0.3) \times 10^{-8}$ reported by us earlier.

An extremely significant result obtained by us is the observation of ^{26}Mg excess due to decay of the short-lived nuclide $^{26}Al(\tau = 1$ Ma) and of ^{41}K excess due to the decay of ^{41}Ca ($\tau = 0.15$ Ma) in the same mineral phase (hibonite) within a Efremovka CAI (**Fig. 3.11**). This is the first observation of correlated excess of two short-lived radionuclides in early solar system objects at a microscopic scale. We have also analysed refractory phases in a CAI from the meteorite Allende, where previous studies showed only marginal presence of ^{26}Mg excess, and found no evidence for ^{41}K excess in it.

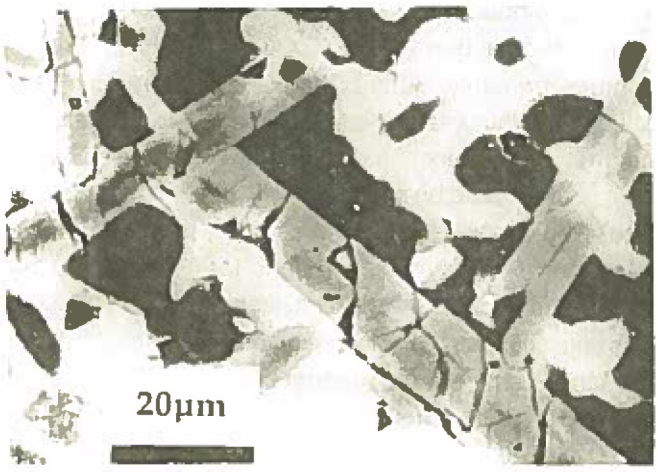


Fig.3.11 Scanning electron micrograph of hibonite grains (the long bars) in the Efremovka CAI E50.They contain excess ^{41}K and ^{26}Mg, indicating that their parent nuclides $^{41}Ca(\tau=0.15$ Ma) and $^{26}Al(\tau=1$ Ma) were present in the solar nebula and were incorporated "live" into these hibonites at the time of their formation in the solar system.

These data strongly suggest correlated presence (or absence) of the short-lived nuclides ^{26}Al and ^{41}Ca in the early solar system objects and point towards a single stellar source and/or process responsible for production and subsequent introduction of these two nuclides into the solar nebula. This observation has provided important constraints for the theoretical models proposed to explain the production of these short-lived nuclides in different stellar sites.

(J.N. Goswami, S. Sahijpal and G. Srinivasan)

Stellar Source for Freshly Synthesized ^{41}Ca

A proposal was recently made (prior to our observation of ^{41}Ca excess in Efremovka CAIs) that several of the short-lived nuclides that are present in the early solar system (e.g. ^{26}Al, ^{60}Fe and ^{107}Pd) were produced in a single thermally pulsating asymptotic giant branch (TP-AGB) star and were transported to the solar nebula via AGB wind. In collaboration with the scientists who proposed this model, we have performed calculations to see if one can account for the observation of ^{41}Ca in the

early solar system, in a self-consistent manner, in the TP-AGB model. ^{26}Al is produced in the TP-AGB star during H-shell burning and ^{41}Ca is produced via n-capture primarily during the He-shell burning phase. Making certain plausible assumptions to obtain the neutron source function, it was shown that a TP-AGB star could indeed be a plausible source for ^{41}Ca as well. These calculations also constrained the time interval between the final synthesis ^{41}Ca in the TP-AGB star and the formation of the first solar system solids to ~ 0.6 Ma. The time scale for the collapse of the proto- solar cloud to form the Sun, therefore, cannot be more than this value and imply a rather dense molecular cloud fragment with $n(H) = 5 \times 10^3$ cm^{-3}.

(J.N.Goswami)

Isotopic Studies of Sulfur and Calcium in Meteoritic Sulfide and Carbonates

Carbonate and sulfide phases in meteorites are generally considered to be products of secondary processes occurring on the parent bodies of meteorites. However, rare occurrences of specific mineral assemblages that contain such phases led to the suggestions that there could be instances when certain sulfide and carbonate phases could have been initially formed in the solar nebula. One such set of samples were located in a carbonaceous xenolith present within a non-carbonaceous meteorite, Eravan. The carbonate phases in this xenolith occur as small rounded fine grained aggregates that have extremely pure composition, and without any associated secondary phases (e.g. dolomite, iron sulphide) commonly co-existing with meteorite carbonates, and are proposed to be of nebular origin. An unique phosphorous-rich sulfide grain, was also found in this xenolith (**Fig. 3.12**). The association of phosphorous with sulfide is rather unusual and led to the suggestion that the P-rich sulfide is a nebular condensate and represents the first sulfide phase to form in the solar system.

To test the proposed nebular origin of these rare phases we have developed analytical procedures to carry out sulfur isotopic studies with our ion microprobe, and have analysed sulfur isotopic composition of the P-rich sulfide and calcium isotopic composition of the carbonate phases. Our analysis of carbonate phases failed to reveal any anomaly in the isotopic composition of ^{42}Ca, ^{43}Ca and ^{48}Ca relative to ^{40}Ca and ^{44}Ca that were used as reference isotopes. We have also performed fourteen sulfur isotopic analysis of the P-rich sulfide grain, alongwith troilite from Cape York iron meteorite, that was used as an internal standard. Again no sulfur isotopic anomaly could be found, and, in particular, the neutron-rich isotope ^{36}S has normal composition. It has been well established that many of the refractory phases representing early nebular condensates show isotopic anomalies in neutron-rich isotopes of Ca (^{48}Ca) and Ti (^{50}Ti). The absence of neutron-rich isotopic anomaly in both the sulfide and carbonate phases, as well as normal isotopic compositions for the other S and Ca isotopes in these phases suggest that they are not nebular condensates.

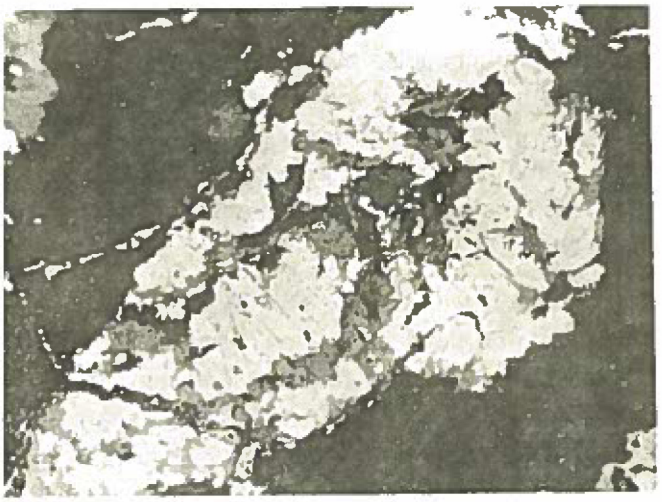


Fig. 3.12 An unusual sulfide grain (100x40 micron) rich in phosphorous found in a carbonaceous inclusion inside a non-carbonaceous meteorite, Eravan. Ion probe studies of sulfur isotopes did not reveal any anomalous composition.

(J.N. Goswami and S. Sahijpal)

Nitrogen Isotopic Composition in Phase-Q of Chondrites

A major fraction of the primordial noble gases in chondritic meteorites are located in a small acid resistant carbonaceous phase (named phase-Q). Further treat-

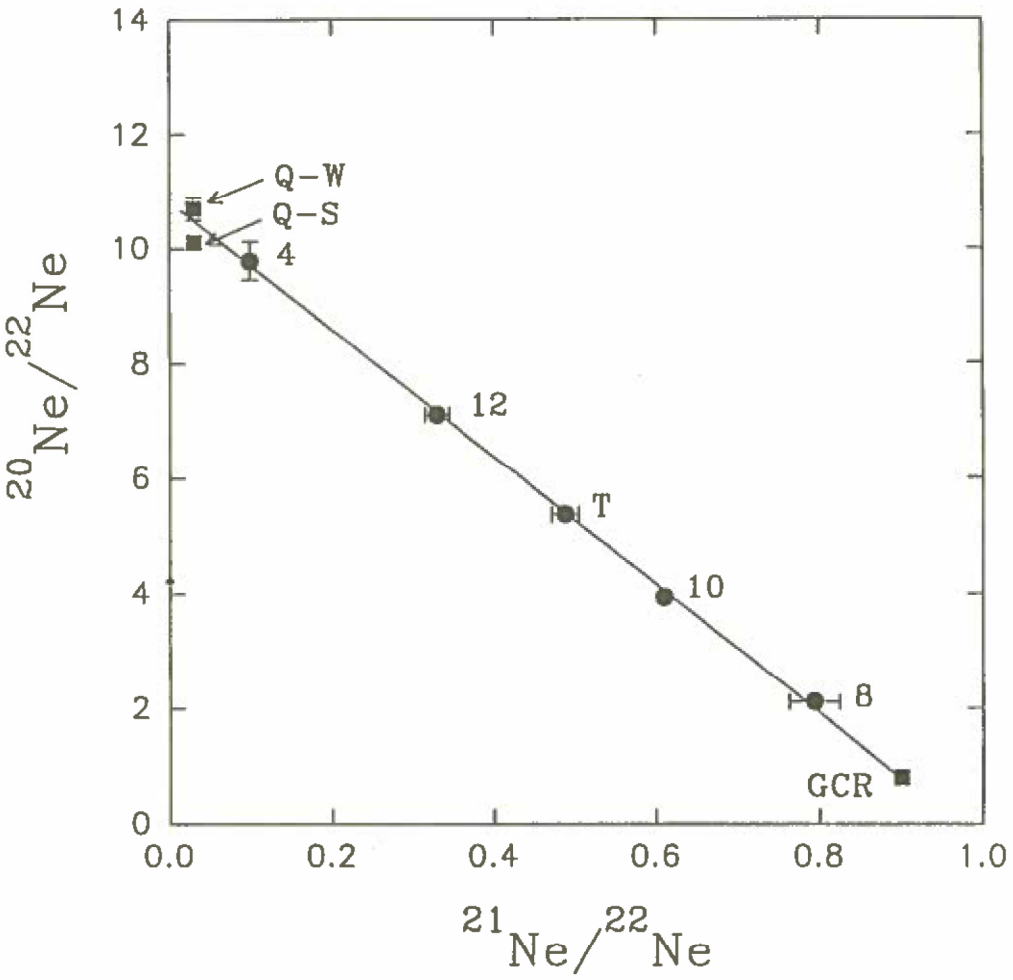


Fig. 3.13 Ne three isotope plot for Dhajala acid residue. Temperature in hundreds of degrees is indicated for each point. T is for the total. Q-S and Q-W are the literature values for Ne-Q, derived from Dhajala and Murchison respectively.

ment of this phase with oxidising acids like HNO_3 leads to loss of the isotopically normal planetary gases but retention of exotic noble gas components, mostly of extra solar origin, without appreciable mass loss. In the Dhajala meteorite, the abundance of exotic noble gas component is shown to be negligible. Therefore the acid residue of Dhajala is considered to host pure component of Q-gases. The Q-component from different chondrite groups defines a uniform composition for all the noble gases except for a possible difference in the $^{20}Ne/^{22}Ne$ ratio between ordinary and carbonaceous chondrites. It will be logical then to ask whether the nitrogen accompanying the Q-component is likewise uniform in composition in different meteorites. No information on the composition of nitrogen in phase-Q is currently available. A study of the acid resistant residue from Dhajala meteorite should provide an unambiguous identification of the N composition in phase-Q.

A stepwise temperature extraction studies of Dhajala acid residue have revealed a uniform isotopic composition for all the trapped noble gases which match the Q-component. Ne and N data reveal some important features. The Ne data are shown in a three isotope plot in **Fig. 3.13**. All the data points fall along a mixing line between cosmogenic and a trapped component. From the least square fit through these data points, we derive the $^{20}Ne/^{22}Ne$ of the trapped component to be

10.45±0.15. This value is in agreement with the literature value of 10.1±0.2 from Dhajala Q-phase. It also agrees with the value of 10.7±0.15 from Q-phase of carbonaceous chondrites. A possible compositional difference in Ne-Q from ordinary and carbonaceous chondrites as earlier advocated by some workers, may not exist.

$\delta^{15}N$ is uniform in all the major release fractions, and we interpret this as the signature of nitrogen in the Q-phase of Dhajala. The uniformity of $\delta^{15}N$ in all temperature fractions, similar to the uniform isotopic composition of noble gases clearly shows that Q-N has a well defined composition of $\delta^{15}N$ (‰) = -14.93±0.42.

The temperature release pattern of noble gases and nitrogen from the acid residue of Dhajala shows a peak release of noble gases at 1200°C, while the peak release of nitrogen occurs at 1400°C and about 17% N is still released at 1700°C. This clearly shows that nitrogen is more tightly bound and needs a higher activation energy for release as compared to the noble gases. Whereas noble gases are mostly sheltered at adsorption sites in the amorphous carbon of Q-phase, nitrogen could be chemically bound to the carbon and hence require a higher activation energy for release.

(S.V.S. Murty)

Nitrogen, Noble Gas and Nuclear Track Studies of the Martian Meteorite ALH84001

ALH84001 is a recently discovered martian meteorite. It is different from the other martian meteorites in its mineral composition, presence of pre-terrestrial weathering products and its older crystallization age. It probably represents a sample of the ancient martian crust. We undertook a simultaneous study of nitrogen, noble gases and nuclear tracks in this meteorite in an effort to look for the nitrogen and noble gas components in martian atmosphere and mantle and also to delineate the formation and evolution history of the meteorite.

The formation age of this martian meteorite was obtained from the argon isotopic data. We determine a K-Ar age of 3.8 Ga, using a K content of 108 ppm. This age is much higher than the crystallisation age of ~1.3 Ga for the other known martian meteorites. We have used the measured neon isotopic abundance and appropriate cosmogenic production rate to obtain an exposure age of 16.4 Ma for this meteorite. Like its formation age, the cosmic-ray exposure age of ALH84001, is also significantly higher compared to exposure ages of other martian meteorites that group around the values of 2.5 and 10 Ma. These data therefore suggest that ALH184001 sampled an ancient site on Mars and a separate impact event at ~ 16 Ma is needed for its ejection from Mars.

Cosmic ray heavy nuclei tracks were studied in ALH84001 to determine its pre-atmospheric mass and size and hence the extent of atmospheric ablation suffered by it. Numerical studies of dynamical transfer of ejecta from Mars and Asteroids to Earth suggest that martian ejecta should enter the earth's atmosphere with a much lower velocity than ejecta from asteroids. Martian meteorites are therefore expected to suffer lower level of atmospheric ablation compared to meteorites derived from asteroids. Our earlier studies of three martian meteorites suggested atmospheric ablation of ~ 50-60% for them that is consistent with expectation from dynamical modelling. A detailed study of nuclear tracks in ALH84001, however, show that the atmospheric ablation is rather high (~ 85%). The cosmogenic isotope and track data are suggestive of a complex exposure history for this martian meteorite.

Studies of the heavy noble gases (Xe and Kr) in ALH84001 showed that the isotopic ratios $^{129}Xe/^{132}Xe$ and $^{136}Xe/^{132}Xe$ are as high as 2.22 and 0.347 respectively, very close to the values found in a fragment of another martian meteorite EET79001, C. But the elemental ratio $^{84}Kr/^{132}Xe$ is very low (~ 6), unlike in EET79001,C where this value is ~ 25. This most probably indicates the presence of an elementally fractionated noble gas component from the martian atmosphere. Carbonates formed by low temperature aqueous alteration processes on Mars have been identified in ALH84001 and it appears to be the probable host of the fractionated noble gas component in this meteorite.

The bulk sample of ALH84001 has 0.75 ppm N with $\delta^{15}N$ = 85.7 ‰. Among the samples analysed, $\delta^{15}N$

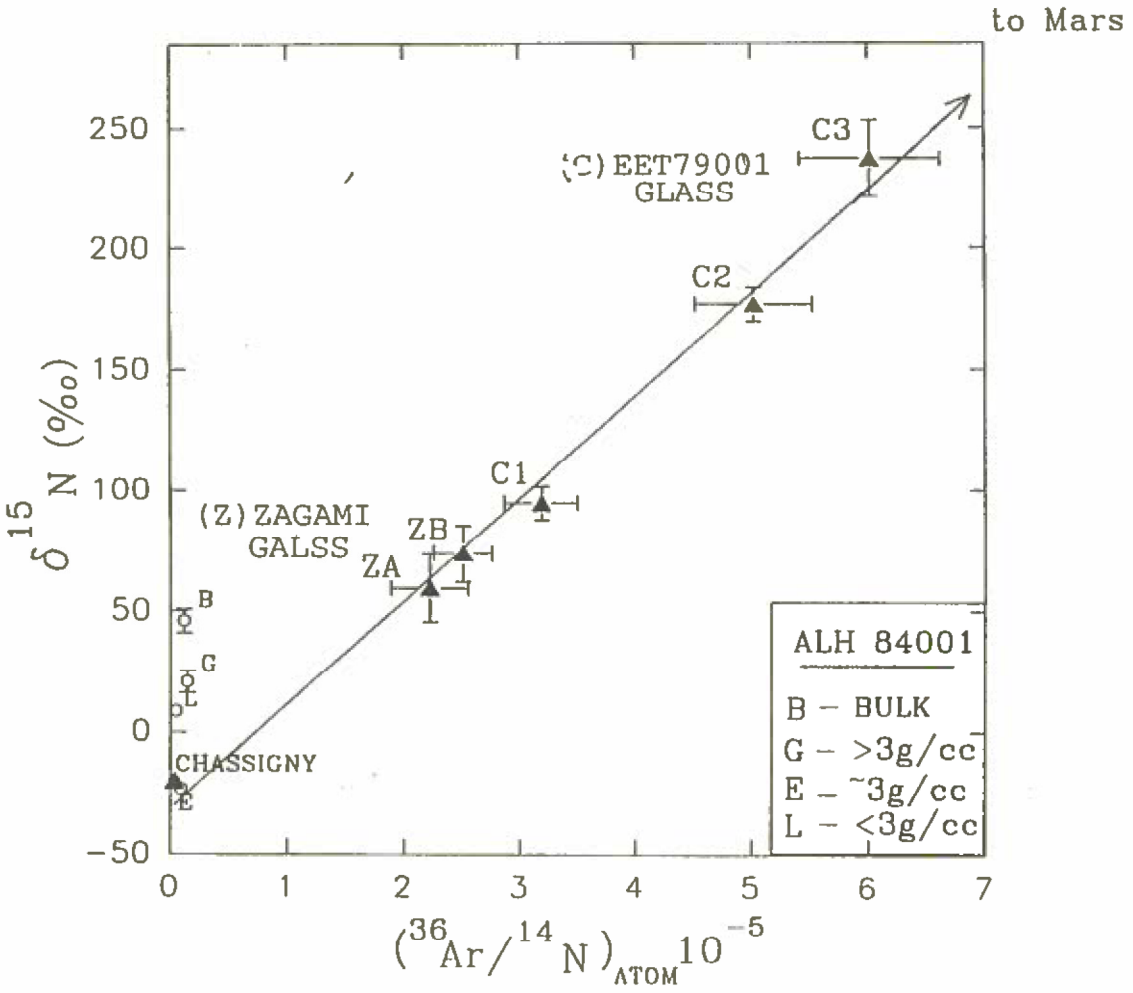


Fig. 3.14 Plot of $\delta^{15}N$ Vs. $^{36}Ar/^{14}N$, both corrected for cosmogenic contribution, shows a linear trend for EET79001 and Zagami. ALH84001 data clearly deviates from this trend and defines a separate line. An elemental fractionation between Ar and N, with preferential intake of N can explain this trend.

varies between a minimum of - 21 ‰ and maximum of 201 ‰ in the bulk sample. Correcting for the cosmogenic contribution we obtain $\delta^{15}N$ (corrected) = 46 ‰ for the bulk sample. Such high positive $\delta^{15}N$ values for trapped N have only been found in the shocked glass of EET79001 and most recently in the shocked glass of Zagami, two other martian meteorites. This clearly indicates the presence of an atmospheric N component in ALH84001. **Fig. 3.14** is a plot of $\delta^{15}N$ versus the elemental ratio $^{36}Ar/^{14}N$, both corrected for cosmogenic contributions. Whereas the glassy lithologies of EET79001 and Zagami represent a mixing trend, the data of ALH84001, define another distinct line. An elemental fractionation wherein N is preferentially taken compared to Ar can generate such a trend. This elemental fractionation is also consistent with the fractionation observed in noble gas elemental ratios and could plausibly be explained as due to the physical processes by which noble gases are incorporated into the weathering products on the martian surface.

(C.J.Clement, J.N.Goswami, R.K.Mohapatra, S.V.S.Murty and Nirjhari Sinha)

Thermal Neutron Source Function for Meteorite Bodies

We have, over the past years, successfully determined the high energy proton and neutron source functions within meteorites of different sizes exposed to cosmic rays in the interplanetary space and now we have taken up the problem of thermal neutron source function within these objects. Theoretical calculations are available for the depth profiles of thermal neutrons but earlier studies of Dhajala meteorite fragments based on ^{60}Co which is produced by thermal neutron capture on ^{59}Co showed that some serious discrepancies exist in the calculations.

Several fragments of Mbale meteorite which fell in Uganda in 1992 were studied for this purpose. To start with, we have determined the cosmic ray exposure age of this meteorite using neon isotopes to be 26.9 Ma. Using track density measurements, we have established that it was a small body in space (radius about 35 cm). ^{60}Co was measured in several fragments of this meteorite which provide the neutron fluence and simultaneously track densities were measured which provide the effective shielding depth of each fragment within the meteoroid body. Combining these data, a source function of thermal neutrons has been constructed for Mbale that has a smaller pre-atmospheric size (R~35 cm) compared to Dhajala (R~110 cm). The results show that the observed depth profiles of ^{60}Co in Mbale as well as in Dhajala are different from the expected profiles calculated using theoretical neutron transport function within the meteorites. Further work is being done to understand the cause of this discrepancy.

This work is being done in collaboration with Dr. G.Heusser of Max Planck Institut, Heidelberg.

(N. Bhandari, C.J. Clement, S.V.S. Murty and K.M.Suthar)

Solar Flare Tracks in Rio Negro Meteorite

The Rio Negro (L4) chondrite has shown the presence of solar component in helium and neon isotopes. A search was therefore made for solar flare tracks in the Rio Negro Meteorite. The track density is found to exhibit a bimodal distribution, the lower peak (10^4- 10^5 /cm^2) is attributed to heavy nuclei of galactic origin and the higher peak ($6x10^6$- $2.5x10^7$/cm^2) to solar flare nuclei. Near absence of grains with steep gradients or very high track density > 2.5×10^7 show that the precompaction irradiation environment of Rio Negro was similar to carbonaceous chondrites.

This work was done in collaboration with Instituto di Cosmogeofisica, Torino.

(N. Bhandari and K.M. Suthar)

MACROSCOPIC PHYSICS

ASTROPHYSICS

Large Scale Structure

Detailed statistical properties of clusters and voids present in various regions of the sky surveyed by the CfA catalogue were analyzed using a technique developed earlier by us. The results are in accord with those obtained for a small region of the sky. The significance of these results for various theories of structure formation is being investigated.

(J. Anosova, S. Iyer and R.K. Varma)

Charge Dynamics in Dusty Plasma

In an earlier work on dusty plasma with grain charge fluctuations, the charge dynamics was treated in an ad hoc fashion. On the one hand, charge dynamics was related with the plasma density, potential etc., while on the other hand the effects of charge variation were not considered in electron and ion equations. We have developed a set of fluid equations which describes dust charge dynamics in a self-consistent manner. We have shown that when electron or ion dynamical time scales are important, the dynamical equation presented by us gives significant alteration of the results obtained by including the charge dynamics in an ad hoc fashion. Besides, the charge dynamic equation is valid even when electron and ion distributions are non-Maxwellian. This work was done in collaboration with B.P. Pandey.

(J. R. Bhatt)

New Jeans Length in a Dusty Plasma

It is well known that self-gravitating systems are subjected to a condensational instability called Jeans instability. The latter arises when the wave-number k of the perturbation becomes less than a certain critical wave-number k_j (Jeans wave-number). All the perturbations with $k < k_j$ then become isolated as self-gravitating blobs.

In this work, we have investigated the Jeans instability of a self-gravitating, unmagnetized dusty plasma and reported the following results: (i) The spectrum of the instability crucially depends upon a dimensionless parameter, signifying the strength of the gravitational interaction of the dust over its electromagnetic interaction. (ii) The charge fluctuations can enhance the strength of the instability and reduce the Jeans length. The estimate of the Jeans mass of a self-gravitating dusty plasma can drastically reduce due to the charge fluctuations as compared to the constant charge case. This work was done in collaboration with B.P. Pandey.

(J. R. Bhatt and D. Banerjee)

Magnetohydrodynamic Equilibrium around a Compact Object - I

The efficiency with which gravitational potential energy is released from the material gas which accretes onto highly compact objects makes accretion disks the most popular models of the luminous objects. Accretion disks can be classified into two classes: thin and thick. The study of thick accretion disks is important due to the following reasons: (i) Such structures presumably form in nature, e.g. in AGNs and around protostars. (ii) Thick disks are often invoked to generate the outflows and collimated jets. We have, therefore, started a systematic study of thick disks around a magnetized compact object. A major aim of our work was to analyze the role of a toroidal magnetic field in the thick disk equilibrium. In magnetized disks, the gas is expected to be tied to the magnetic field and its inertia can cause the magnetic field lines to bend backwards by creating a toroidal component of the magnetic field, which in turn may collimate a hydromagnetic flow over large distances forming jets. In the present work, we begin by analyzing the equilibrium structure of a pressure supported disk in the presence of the dipolar magnetic field of the central object. Our main results are: (i) Pressure and density profiles are strongly influenced by the self-consistently generated toroidal component of the magnetic field; (ii) In the limit of vanishing toroidal component of magnetic field, we find that the solutions thus obtained are stable; (iii) The magnetic topology shows that kinks develop in the field line structure and there is a shear in the field structure due

to the toroidal component of the field line.

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

Magnetohydrodynamic Equilibrium around a Compact Object (Schwarzschild Black Hole) - II

In many accretion scenarios, the central objects are very massive and, therefore, the effects of the general theory of relativity plays an important role in determining the dynamics and structure of the accretion disks. Keeping this in mind, we have recently completed a work carrying out the study of a thick accretion disk around a magnetized Schwarzschild black hole in the presence of a self-consistently generated toroidal magnetic field. We find the exact solutions of disk equilibrium, which generalises the earlier results obtained within Newtonian gravity. The effect of strong gravitation puts constraints on the strength of the toroidal magnetic field, which is suppressed in the vicinity of the black hole as well as helps in compressing the vertical height of the disk. We have also studied the single charged particle trajectories near a black hole in the presence of plasma. Our results indicate that the plasma disk may be unstable around the black hole.

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

Trajectories of Charged Particles around a Slowly Rotating Compact Object

We have discussed the trajectories of charged particles in a dipole magnetic field and quadrupole electric field superposed on the external spacetime of a very slowly rotating mass represented by a first order correction to the Schwarzschild geometry. The metric which is an approximate form of the Hartle-Thorne metric includes corrections of the linear order in $2\omega = \left[\frac{2j}{r^3}\right]$ only. Trapped bound orbits exist both for co- and contra-rotating particles as evidenced from the structure of the potential wells for various combinations of the physical parameters.

(A.R. Prasanna and Anshu Gupta)

Reversal of Centrifugal Force for Slowly Rotating Compact Object

Studies are in progress to find the nature of the centrifugal force acting on a test particle orbiting (1) outside a slowly rotating relativistic object and (2) inside a slowly rotating relativistic object, by considering the Hartle-Thorne metric for various matter distributions and the possibility of existence of equilibrium configurations wherein the pressure gradient force balances both gravitational and centrifugal forces such that the body does not collapse beyond the event horizon and turn into a black hole.

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

Structure of Electromagnetic Fields of Rotating Neutron Stars

We consider the electromagnetic field structure near a rotating compact object like a neutron/quark star. The magnetic and electric field structure with monopole corrections to the Hartle-Thorne metric has been calculated. The field structures inside the star are also being studied using the Hartle-Thorne formulation for compact stars that are uniformly rotating, axisymmetric fluid configurations.

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

METEOROLOGY AND CLIMATE STUDIES

Climate Modelling

The major work done in the last year was a developement of a General Circulation Model (GCM). The model consists of 21 waves in horizontal and 6 levels in the vertical. Orography appropriate for 21 waves has been included in the model. The various physical processes incorporated in the model are the following: The convective process is parameterized through modified Kuo's scheme. A stable condensation process is also included in the model. The super lapse rate is replaced by a neutral sounding by a dry adjustment scheme. The constant flux layer is parameterized by using bulk aerodynamic formulae. The vertical eddy

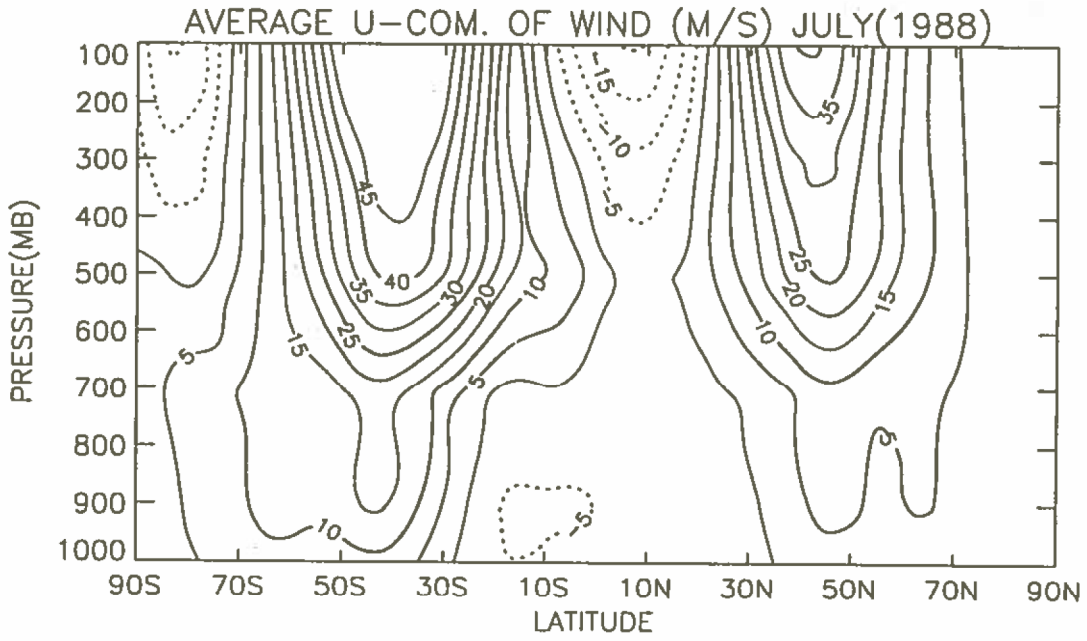


Fig. 4.1 Model simulated zonal component of wind for July 1988.

transport in the free atmosphere is parameterized using mixing length formulation. A linear second order horizontal diffusion formulation is used in the model. Calculations of long and short wave radiation fluxes are based on emissivity/absorptivity methods. In the radiative calculation, diurnal cycle is included. The low, middle and high clouds are parameterized based on threshold relative humidity from model and hence it is interactive. The model is integrated for 46 days starting from June 15, 1988, and the average zonal component of wind for the last 30 days is taken as representative for the month of July. The **Fig. 4.1** shows the zonal component of wind for July 1988. The July simulation agrees well with July climatology. Simulation of winter climate (January) is in progress.

(B. Thomas, S.V.Kasture and V. Satyan)

Stationary Kelvin and Rossby Waves

In order to study the effect of nonlinearities on the stationary Kelvin and Rossby waves, we have used linear and nonlinear versions of a five-level global spectral model. By comparing the response of the idealised heating, the impact of nonlinearities on the horizontal and vertical structures of the stationary Kelvin and Rossby waves is determined. The influence of the nonlinear terms is mostly noticed in the vicinity of the forcing region. The upper tropospheric circulations in the nonlinear response revealed the eastward displacement of the anticyclonic vorticity and horizontal shift of the maximum equilibrium divergence relative to the prescribed heating. These nonlinear effects are found to be quite sensitive to the vertical structure of diabatic heating. Nonlinearities in the presence of convective heating appear to produce a vertical shift of low level circulation anomalies which result in anomalous equatorial westerlies over forced Rossby regime in the middle troposphere. It was also found that nonlinearities generate strong ageostrophic motions in the low latitudes and modify the vertical shear and the structure of mean zonal flow. This work was done in collaboration with R. Krishnan.

(S.V.Kasture)

PLASMA PHYSICS

Instability in Partially Ionized Plasmas

A magnetized inhomogeneous, weakly ionized plasma is shown to be unstable under the limit of high frequency ($\omega >> kV_A$, kC_S) and low frequency ($\omega << \nu_{in} << \omega_{ce}$) modes. Cross field current provides the free energy for the instability in the absence of gravity, neutral drag and compressibility of neutral gas. However, the presence of the above mentioned physical quantities can change the scenario by producing a variety of modes under different conditions pertaining to scale sizes and collision frequencies. The characteristics of different modes are discussed in detail. Growth rates for different modes for weakly as well as strongly coupled and weakly resistive plasma are obtained. It is shown that the growth rate for different modes is very sensitive to the ratio of neutral and ion density, collision frequency of neutrals with ions and scale heights associated with density gradient and magnetic field. We find that the instability occurs when the density and magnetic field inhomogeneities are in opposite directions. The potential application of the theory under the present set of approximation is also discussed. This work is being done in collaboration with A.A. Sheikh and C.B. Dwivedi.

(A.C. Das)

Dust-Magnetoacoustic Modes in a Magnetized Dusty Plasma

The study of the so-called "Dusty Plasmas" which consist, in addition to the usual electrons and ions, of finite-size charged dust particles has received much attention in the last few years. Last year, we suggested a model for magnetized dusty plasmas and thereby obtained new types of low - frequency normal modes in such plasmas.

In the present work, we have investigated the existence of various types of magnetoacoustic normal modes using the above model. The latter is essentially an effective two-fluid MHD-like model which allows non-frozen motions of the component fluids. To keep the analysis tractable, we have considered only the fast-magnetoacoustic modes which propagate exactly perpendicular to the external ambient magnetic field. For frequencies much smaller than the dust particle gyro-frequency, we obtain a magnetoacoustic mode which is a generalization of the usual fast hydromagnetic mode in an electron-ion plasma. In the higher frequency regimes, we have found two new types of normal modes which we call the "Dust-Magnetoacoustic Waves". Both the modes are accompanied by compressional magnetic field as well as plasma density perturbations, and are the electromagnetic generalizations of the dust- acoustic waves in an unmagnetized dusty plasma with thermal electrons and ions. The dispersion relations as well as the frequency regimes for the existence of the various modes have been explicitly obtained. An alternative derivation of the relevant governing equations using an approach similar to that employed in the so-called "Electron-Magnetohydrodynamics" (EMHD) has also been carried out.

(N. N. Rao)

Dust-Ion-Magnetoacoustic Mode in a Magnetized Dusty Plasma

In our earlier work described above, we have shown that depending on the frequency regimes there are two types of modes called "dust-magnetoacoustic waves" which are the electromagnetic generalisation of the electrostatic dust-acoustic mode in an unmagnetized dusty plasma. In the present work, we have found a new type of hydromagnetic wave called "Dust-Ion-Magnetoacoustic" mode which is the generalization of the so called dust-ion-acoustic wave. For frequencies $\omega << Z\,\Omega_i\,(n_0/n_{e0})$, the dust-ion-magnetoacoustic modes are governed by the dispersion relation,

$$\frac{\omega^2}{k^2} = \frac{1}{m_i n_{e0}}\left[n_{i0}\gamma_e T_e + n_{e0}\gamma_i T_i + \frac{n_{i0}}{n_{e0}}\frac{B_0^2}{4\pi}\right]$$

where n_{e0} (n_{i0}), T_e (T_i) and γ_e (γ_i) denote, respectively, the equilibrium number density, the temperature and the adiabatic index of the electron (ion) fluids, m_i is the ion mass, Z is the dust charge number, n_0 is the dust number density, Ω_i is the dusty gyro-frequency, and B_0 is the ambient magnetic field. In the limit $B_0 \to 0$, the above

dispersion relation exactly reduces to that of the dust-ion-acoustic waves.

(N.N. Rao)

Self-Similar Expansion of a Warm Dusty Plasma

Plasma expansion is fundamental process which is important whenever there exists a free boundary across which the plasma can flow. In the present work, we have analysed the self-similar expansion into vacuum of a warm dusty plasma filling the semi-infinite half-space. The following two cases have been considered :

Unmagnetized Case : For unmagnetized dusty plasmas, we include the adiabatic equation of state for the dust component whereas the electrons and the ions are assumed to be thermal having Boltzmann distributions. Exact analytical solutions are obtained for the case of cold dust fluid with positive as well as negative charging of the dust grains. For the warm case, expansion profiles are obtained by numerically solving the relevant self—similar governing equations. It is found that an isothermal negatively charged dust fluid expands over a larger distance than an adiabatic one. On the other hand, for a given set of parameter values, a plasma with positively charged dust expands farther than the one with negatively charged dust. Typical expansion profiles are shown in **Fig. 4.2**. This work was carried out in collaboration with R. Bharuthram.

Magnetized Case : For magnetized dusty plasmas, we have investigated the self-similar expansion in a direction transverse to the ambient magnetic field. The analysis is carried out using a MHD model wherein the plasma expansion preserves charge neutrality and the magnetic field lines are frozen to the plasma. The self-similar governing equations obtained from the model equations are reduced to a quadrature. Analytical solutions for a number of cases of practical interest are obtained both for the isothermal as well as for the adiabatic expansions. It is found that the ambient magnetic field constrains the transverse expansion of the plasma. For sufficiently strong magnetic fields, the dust number density falls off to nearly zero at much shorter distances from the initial plasma-vacuum boundary whereas the expansion velocity is substantially reduced (**Fig. 4.3**). This work was carried out in collaboration with R. Bharuthram.

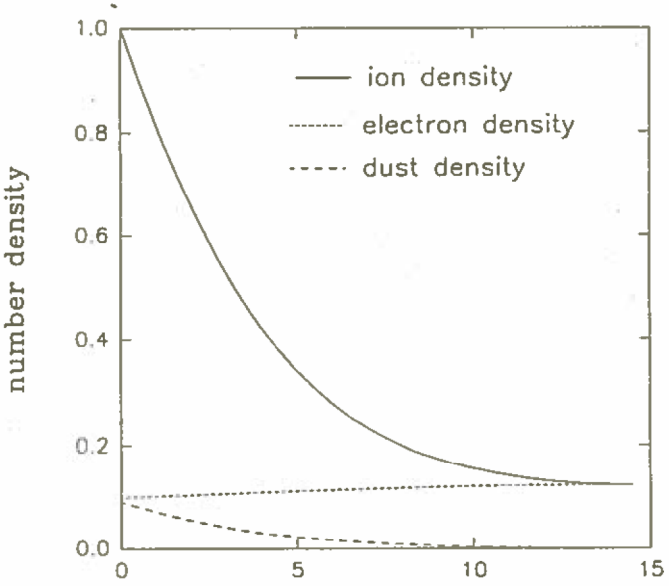


Fig. 4.2 Typical number density profiles as functions of the normalized self-similar variable (ξ) during the expansion of an unmagnetized dusty plasma with negatively charged dust particles ($Z = -10$) which are governed by an adiabatic equation of state ($\gamma = 3$). Other parameters are : $\alpha \equiv T_i/T_e = 0.1$, $\delta \equiv n_{e0}/n_{i0} = 0.1$, $\Delta \equiv p_{d0}/n_{i0} T_i = 0.1$. The electrons and the ions are assumed to be isothermal.

(N.N. Rao)

Nonlinear Dust-Acoustic Waves with Dust Grain Charge Fluctuations

One of the most essential features that distinguish dusty plasmas from the usual multi-component plasmas is that the charge on the dust particles can vary due either to the wave-motion-induced electron and ion currents flowing onto the grain surface or to the equilibrium charging processes. This feature leads to important new effects found only in dusty plasmas. For example, dust grain charge fluctuations can lead to a damping of the linear normal modes in a dusty plasma. However, their effects on nonlinear waves have not been investigated so far.

In our work, we have studied the propagation of nonlinear dust-acoustic modes by taking into account the grain charge fluctuation dynamics. For small, but finite, amplitudes the waves are shown to be governed by a Boussinesq-like nonlinear wave equation which is coupled to the charge fluctuation equation derived from the current balance equation. For uni-directional propagation of the waves, the coupled equations can be reduced to a Korteweg-de Vries equation with a source term. At early times, the localized solutions of the latter equation are found to be damped due to the dust charge fluctuations. This result is consistent with the predictions of the linear theories. This work was carried out in collaboration with P.K. Shukla.

(N.N. Rao)

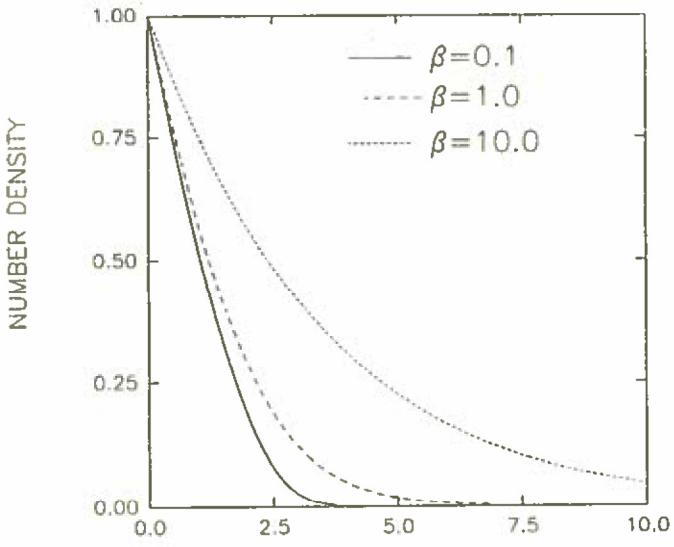


Fig. 4.3 Dust fluid number density profiles as functions of the normalized self-similar variable (ξ) during the adiabatic (γ=3) transverse expansion of a magnetized dusty plasma for different values of the plasma-beta parameter, $\beta \equiv C_S^2 / V_A^2$. It is seen that the magnetic field constrains the transverse expansion of the dusty plasma. The other parameter is : $\alpha \equiv p_{d0} / (B_0^2 / 4\pi) = 0.1$

Linear and Nonlinear Rayleigh-Taylor Modes in Non-uniform Dusty Magnetoplasmas

The linear and nonlinear properties of Rayleigh-Taylor modes are examined in nonuniform multi-component dusty magnetoplasmas, taking into account the effects of warm ions and the parallel electron dynamics. For this purpose, we have derived a set of nonlinear equations by employing the hydrodynamic equations for the dusty plasma components. In the linear limit, it is found that the increment of the Rayleigh-Taylor instability is impeded due to the parallel electron inertial effects and the presence of static charged dust grains. The nonlinear mode coupling equations admit vortex structures and dipolar vortices as possible stationary solutions. The relevance of our investigation to space and laboratory plasmas is pointed out. This work was carried out in collaboration with P.K. Shukla.

(R.K. Varma)

A New Dust-Dynamics-Induced Interchange Instability in Dusty Plasmas

A nonuniform dusty plasma held in equilibrium in a magnetic field against gravity has a polarization electric field $\mathbf{E}_0$ in the direction of gravity for negatively charged dust grains. It is shown that the $\mathbf{E}_0 \times \mathbf{B}_0$ drift of the plasma which carries a positive current induces, in combination with compressible dust dynamics, a novel flute-like interchange instability that is different from the usual Rayleigh-Taylor mode.

A transverse plasma density perturbation with a wave-vector in the $\mathbf{E}_0 \times \mathbf{B}_0$ direction coupled with a longitudinal (compressible) negatively charged dust density perturbation with the same wavevector produces a charge wave with an inhomogeneity in the direction of $\mathbf{E}_0$ (or equivalently g). The $\mathbf{E}_1 \times \mathbf{B}_0$ drift resulting from the charge wave then enhances the latter, if the equilibrium density is inverted with respect to the gravity. This work was carried out in collaboration with P.K. Shukla.

(R.K. Varma)

MICROSCOPIC PHYSICS

ATOMIC AND MOLECULAR PHYSICS

Oscillator Strengths

Since atomic oxygen is one of the most abundant elements in the solar system and interstellar medium, it can be used to determine physical conditions of the observed matter. Therefore accurate f-values for its lines are needed to determine its abundance. We have performed elaborate configuration interaction calculations for the oscillator strengths of the intercombination lines at λ 1358 and λ 1359 A in the UV region, also observed in the upper atmospheres of Mars and Venus. Since the transition $2s^2 2p^4\ ^3P \rightarrow 2s^2 2p^3\ 3s\ ^5S^0$ is spin forbidden in the LS coupling, a semi-relativistic approach is adopted including spin-orbit, spin-spin, spin-other-orbit, mass correction and Darwin terms of the Breit-Pauli Hamiltonian in the non-relativistic Hamiltonian. These intermediate coupling calculations are performed by including all important correlation effects in a systematic way to obtain converged results. The present results for the $2s^2 2p^4\ ^3P_2 \rightarrow 2s\ ^2 2p^3\ 3s\ ^5S^0_2$ transition differ by 20% from the earlier best calculation which does not include 2p - 4f replacement configurations which account for the ground state polarization and also neglect high lying terms. We, therefore, believe that present results are most accurate and will have important consequences on the abundance determination in the interstellar matter. The atomic structure calculations for C II are in progress.

(K.S. Baliyan)

Photoionization of the Excited States

Information on the excited state photoionization of ions is very poor despite their demand for various applications. In the present work we discuss photoionization of the $2s2p^4\ ^4P$ first excited state of the Cr^{17+} ion which is used in the fusion plasma diagnostics as impurity ion. Apart from the motivation for evaluating accurate photoionization cross sections, the objective was to test the codes here at PRL on the IBM RISC 6000 workstations. The lowest six target states are used in the R-matrix basis function expansion. The CI wavefunctions for these states, and the initial bound and the final continuum (N+1)-electron wavefunctions are obtained in a consistent manner and compared with our earlier calculation on CRAY-YMP. The identical results in the two calculations provided the confidence in the proper functioning of the codes. The calculations are performed including fifteen continuum functions to get converged results in the energy range of interest. Partial as well as total cross sections are calculated in the length and velocity forms of dipole operator. The cross sections are dominated by Rydberg series of resonances, caused by the interference of direct and resonant processes, and provide significant contribution to the total cross sections.

(K.S. Baliyan)

Electron Impact Excitation

Electron excitation data on the oxygen isoelectronic sequence ions are scarce. To meet this requirement we have investigated this problem. We have already completed the calculations for Ca XIII ion of this sequence. Here we consider electron impact excitation of Mg V. Due to open 2p subshell, this system poses great computational complications and one has to include large number of configurations in the representation of target states to achieve reasonable accuracy. The target wavefunctions for the lowest fourteen states are constructed using six orthogonal atomic orbitals. The oscillator strengths between these states and their energies are compared with the available values to ensure the good quality of wavefunctions. Full exchange calculation was carried out at CRAY including all partial waves with angular momentum upto twelve. The No-Exchange calculation was carried out at IBM workstation with l between 13 and 35. This leads to converged results for all dipole forbidden transitions. In order to get converged results for dipole allowed transitions, Burgess and Sheorey sum rule is used beyond $l = 35$. In the low incident electron energy region a rich resonance structure dominates the collision strengths, particularly for dipole forbidden transitions. The results are obtained for all the transitions among

14 target states upto an incident electron energy of twentyfive Rydbergs. This work is done in collaboration with A.K. Bhatia.

(K.S. Baliyan)

Excited-state to Excited-state Transitions of Hydrogen-like Ions in the Coulomb Glauber Approximation

The study of excited-state to excited-state transtions of hydrogen-like atoms by electron impact is an ongoing project. This year we have calculated cross sections and rate coefficients over a wide range of temperature for nlm $\rightarrow$ n'l'm' excitation of HII, HeII and CVI by electron-impact for which the principal quantum numbers n and n' are ≤ 8 in the Coulomb Glauber approximation. These results are compared with some other theoretical results wherever available.

(H.S. Chakraborty and D.P. Dewangan)

Closed Form Expression of the Coulomb-Glauber Amplitude for Arbitrary nlm $\rightarrow$ n'l'm' Excitation in the Limit of Infinite Z_T

We have studied the dependence of the scattering amplitude on the nuclear charge Z_T for excitation of hydrogen-like ions. We have derived a closed form expression for the scattering amplitude in the Coulomb Glauber approximation for an arbitrary nlm $\rightarrow$ n'l'm' excitation in the limit of infinitely large Z_T. We have investigated the Z_T dependence of the cross sections for a number of excited-state to excited-state transions and have found that, as Z_T increases for a fixed energy, the cross sections tend to the limiting form ($Z_T \rightarrow \infty$) and the convergence is faster at higher energies.

(H. S. Chakraborty and D. P. Dewangan)

Positron-Hydrogen Scattering in a Multiple Scattering Model

We have employed a multiple scattering model to study the 1s-2s excitation of hydrogen by positron (and electron) impact in the intermediate energy region. In this multiple scattering model, the effects of multiple scattering by positron-electron and positron-nucleus interactions are taken into account by using the Coulomb wave functions in such a way that the correct boundary condition is satisfied. An attractive feature of this model is that it contains a closured second Born term exactly and, in addtion, it includes contributions from both real and imaginary parts of the third and all higher-order Born terms. The Glauber approximation can be obtained by introducing further approximations in this model. We are now extending the model to the 1s-2p excitation of hydrogen.

(D.P. Dewangan and S. Chakrabarti)

The Continuum Distorted Wave Theory for Ionization

The angular and energy distribution (the double differential cross section, DDCS) of the electrons ejected in the ionisation process in ion-atom collisions at intermediate and high energies reveal a number of features not accounted for by a first order theory. It has become clear over the years that the physics of these features can be understood by the Coulomb distortions produced by the electron-projectile and projectile-target Coulomb interaction. The first study of the effect of the inclusion of the distortions on both initial and final channels is due to Belkic in his extension to the ionisation of continuum distorted wave (CDW) formulation of Cheshire. The CDW theory has many properties, e.g. (1) it is symmetric in its treatment of initial and final channels; (2) both initial and final channels satisfy the correct boundary conditions, (3) it accounts for 3 important mechanisms for ionisation covering distinct regions of the electron ejection energy, namely, direct ejection of slow electrons giving rise to a zero energy peak, electron capture to continuum (ECC) and binary encounter collisions. Despite these properties, 'peculiarities' of the CDW Ansatz have been known for some time in charge transfer. Recently, Brauner and Macek have exposed logarithmic phase and amplitude divergences in the CDW amplitude, on which basis they have argued to discard the CDW method as a valid theory for ionisation. Considering the physical contents of the CDW theory, we decided to investigate the validity of this theory further. Our main conclusions are:

(1) Phase divergence: Contrary to the claims by Brauner and Macek, the absolute modulus of the CDW amplitude is very smooth on both sides of a point with finite discontinuity. In the physical quantities e.g. DDCS, the presence of the discontinuity is barely noticeable.

(2) Amplitude divergence : We show that this mild logarithmic singularity is integrable and therefore is inconsequential at the level of cross sections. Concerning singularities, the DDCS of all present higher order theories have a mathematical divergence at the ECC peak which is of a much stronger nature than the one under discussion.

The above points show that the CDW approach to ionisation cannot be discarded solely on the basis of the arguments presented by Macek and Brauner. (This work was done in collaboration with Dubé.)

(D.P. Dewangan)

FOUNDATIONS OF CLASSICAL AND QUANTUM MECHANICS

$\Delta^{14}C$ Time Series Analysis Artificial Neural Network

An attempt has been made to formulate a simple model for the Δ^{14} C decadel time series data from tree rings for the past 7000 years. We make use of methods from non-linear dynamics and Artificial Neural Network (ANN).

Our exploratory analysis has indicated that the dynamics underlying the Δ^{14} C time series is chaotic in nature. Further it appears that the 'strange attractor' of the system can be embedded in a euclidean space of dimension 5. Next, we incorporated the method of delays involving vector mapping in ANN. For the actual computations, the data was divided in two parts. The first part was used to fit the model and the second was used for single-step prediction. The model could regenerate (see **Fig. 4.4**) the observed data (see **Fig. 4.5**) with 2 - 3% rms error deviations, while the single-step prediction could be made with 2 - 3% rms error. However, the multi-step predictions were not quite good. In order to improve the multi-step predictions, efforts are being made to refine the model further.

(N. Bhandari, D.R. Kulkarni and J.C. Parikh)

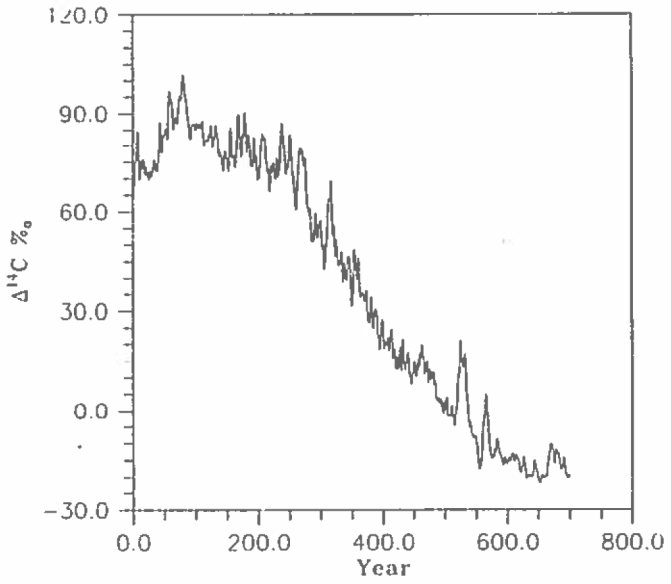


Fig. 4.4 $\Delta^{14}C$ values obtained from the trained ANN

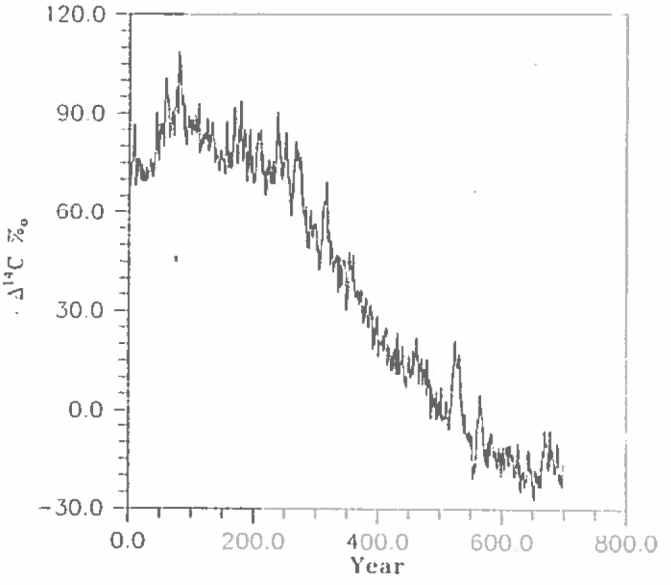


Fig. 4.5 $\Delta^{14}C$ data used in training the ANN

Periodic Orbit Bifurcations and Localized Quantum States

Periodic orbits bifurcate and create new orbits in a variety of ways as system parameters are changed. At and nearby the regions of bifurcations, the standard semiclassical methods fail. However, this classical phenomenon shows up in quantum spectra in ways that are under active study. We have studied the bifurcations and the stability oscillations of the primary channel periodic orbit in the two dimensional coupled quartic oscillator system. These orbits appear to be responsible for a series of localized quantum states. The quantum effects of such stability oscillations of a single, but important, periodic orbit are being studied via the Fourier transform of the quantum density of states. The ongoing work intends to elucidate this further and to look for the effects of classical bifurcations on the wavefunctions and their localization properties. Such phenomena have been very recently observed in the spectra of atoms in external fields.

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

Identification of Localized States in Chaotic Quantum Systems

The morphology of eigenstates of a chaotic quantum system was studied and quantitative measures for a class of localized states were given. For the highly excited eigenstates of a coupled quartic oscillator system it was shown that while information entropy measures are appropriate for the identification of a class of localized states, visual methods are necessary for an unambiguous identification of these states. For certain other types of localization, visual methods appear to be most suitable.

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

Statistics of Time Evolving States in Quantum Chaos

Low dimensional classical systems which are highly chaotic have many simple properties that follow from considerations of ergodicity and mixing as is apparent from the use of statistical mechanical methods in these systems. Quantum chaotic systems, however, do not seem to possess such simplifying features. In order to study this puzzle, we addressed the question of the overlaps of almost arbitrary time evolving states with a complete fixed basis set when the quantum system has either regular or chaotic classical limits. We have found that the statistics of these overlaps "equilibriates" to a Poisson distribution when the corresponding classical system is chaotic while no such stationary distribution is found when the classical limit is regular. Prominent differences are seen when the time evolving states are coherent states.

(V.B.Sheorey and A. Lakshminarayan)

Time Dependent Perturbation Theory

In continuation of our previous work on Time Dependent Perturbation Theory, we have carried out further investigations into the question of convergence of the perturbation series. We have shown that for a class of Hamiltonian systems, it is possible to relate the convergence problem with that of the structure of singularities in complex time of the solutions of the equations of motion for the perturbed Hamiltonian. This implies that the presence of natural boundaries in complex time would be associated with similar natural boundaries for the perturbation theory, which would prevent the analytic continuation of the perturbation theory.

While performing numerical tests of the perturbation theory, it was observed that the numerical results were not very satisfactory for large time, even though the perturbation series was expected to be convergent. We analysed the situation and traced this behaviour as being due to secular terms in the perturbation theory. Higher order terms in the perturbation series were then computed and it was shown that when these were taken into account the results were improved considerably.

These studies were applied to the Henon-Heiles system and to a 2 degree of freedom Hamiltonian where the unperturbed frequencies were functions of the action.

(Mitaxi P. Mehta and B. R. Sitaram)

Differentiability Properties of Invariants of Hamiltonian Systems

Given a Hamiltonian system in n degrees of freedom, we had earlier considered the general properties of solutions of the Liapunov equations and their relation to invariants of the system. We have now succeeded in writing explicit evolution equations for the derivatives of the invariants along phase space directions. We have shown that the solutions of these equations exist whenever the solution of the equations of motion is analytic in a strip including the real t-axis. Under these conditions, the invariants are thus guaranteed to be infinitely differentiable in directions transverse to the orbit and analytic along the orbit. A simple example, which shows the existence of invariants which are not analytic in directions transverse to the orbit has also been derived.

(B. R. Sitaram)

Lie Symmetries and Liapunov Exponents

It is well known that for a Hamiltonian system with bounded motions, the existence of an invariant forces two of the Liapunov exponents to vanish. We have shown that, in a similar fashion, the existence of a Lie symmetry forces one Liapunov exponent to vanish.

(B. R. Sitaram)

A Topological Action Principle for Classical Mechanics

A new variational principle for classical mechanics is formulated which seeks to furnish equations for the momentum as a vector field. The principle which yields the required field equation, namely, the Hamilton-Jacobi equation is that the integral around a reducible circuit of the differential form (p dq - H dt) over the space (q,t) vanishes. On the other hand, the stationarity of the circuit integral, in general, over an irreducible circuit is shown to yield conditions which constrain the admissible initial values to a discrete set. This prescription thus constitutes a topological action principle.

(R.K. Varma)

A Re-interpretation of Heisenberg's Construction of Quantum Mechanics in Terms of Trajectories

The construction given by Heisenberg defining the kinematics and the dynamics of quantum mechanics is revisited with a view to re-interpreting it in terms of the trajectories which have been a central concept of classical dynamics, but which have since been abandoned in the realm of quantum theory. It has been argued here that the concept of trajectories need not be abandoned, but rather ought to be redefined and generalized suitably. The Heisenberg construction has been shown to be retrievable through a suitable Fourier decomposition of trajectories if we introduce on the time line two time variables which are defined to be time-ordered. The quantum jump hypothesis implied in the Bohr theory is also introduced suitably in terms of trajectories, and is shown to lead to the quantum condition $pq - qp = \hbar / i$.

(R.K. Varma)

NUCLEAR PHYSICS

Interacting Particle Gamow - Teller Strength Densities and β-Decay Rates of fp-Shell Nuclei for Presupernova Stars

It is now well established that β-decay rates for A > 60 neutron excess fp-shell nuclei play a very important role in determining the structure of the core of massive presupernova stars and hence on their subsequent evolution towards gravitational collapse and supernova explosion phases. In view of this, we have now developed a method to calculate temperature dependent β - decay rates by writing the expression for the rates explicitly in terms of bivariate Gamow-Teller (GT) strength densities $I^{H}_{O(GT)}$ for a given one plus two-body Hamiltonian $H = h + V$ and state densities of the parent nucleus besides having the usual phase space factors. The earlier theory developed by us for constructing the non-interacting - particle strength densities is applied and then $I^{H}_{O(GT)}$ is constructed using the bivariate convolution form $I^{H}_{O(GT)} = I^{h}_{O(GT)} \otimes \rho^{V}_{O(GT);BIV-G}$. The spreading bivariate Gaussian $\rho^{V}_{O(GT);BIV-G}$ for fp - shell nuclei is constructed by assuming that the marginal centroids are zero, the marginal variances are same as the

corresponding state density variances and fixing the bivariate correlation coefficients ζ using experimental β-decay half lifes. With the deduced values of ζ ($\zeta \sim 0.67$), β-decay rates for ^{61,62}Fe and ^{62,64}Co isotopes are calculated at presupernova matter densities $\rho = 10^7 - 10^9$ gm/cc, temperatures T = (3 - 5) X 10^9 °K and electron fractions $Y_e = 0.43 - 0.5$. The convolution form for $I^H_{O(GT)}$ led to a simple expression for calculating GT non-energy weighted sum rule strength and it describes (within 10%) the shell model results of fp - shell nuclei.

(V.K.B. Kota and D.Majumdar)

Nuclear Spectroscopy in the Chaotic Domain

The structure generating the GOE description of slow-neutron resonance spectra in heavy nuclei, when augmented by a calculable smooth state-density is shown to extend downward in the spectrum, say, to (1 - 2) MeV above the ground state (and upward until particle emission becomes significant). In the resultant extended chaotic domain, calculations of one- and two-point quantities (e.g. single-state occupancies and transition strengths) are relatively simple and are "complete" since (k>2)-point quantities are experimentally inaccessible; they follow from the spectral averaging theory that is being developed. The theory for one-point functions is studied in detail using ^{234}U as an example, the input data being taken from the observed low-lying spectrum and the far-separated neutron-resonance spectrum. This study showed for the first time that the spectral averaging theory is indeed the proper theory for spectroscopy in the "quantum chaotic domian" of complex nuclei. This work was done in collaboration with J.B. French, R.U. Haq and J.F. Smith.

(V.K.B. Kota)

M1 Distributions in the SU_{sd} (3) X 1g ⊗ U(2) Limit of pn-sdgIBM

In order to study the scissors mode, in particular, and M1 distributions, in general, in heavy deformed odd-mass nuclei for which coupling of hexadecupole phonon (vibration) is important, the SU_{sd} (3) X 1g ⊗ U(2) symmetry scheme within the proton-neutron interacting boson-fermion model is developed. The group-subgroup chain is identified, band structures and the corresponding quantum numbers are derived and also produced a simple energy formula for the M1 excited states. It is found that it is essential to use two-body M1 transition operator. A simple one plus two-body M1 operator with four g-factors is constructed and then using SU(3) Wigner - Racah algebra, formulas for M1 strengths are derived. Using this theory, predictions for the ^{157}Gd nucleus, for which experiments are planned at Darmstadt (Germany), are made. This work was done in collaboration with Y.D. Devi.

(V.K.B. Kota)

The $\Delta L = 4$ Staggering in Superdeformed Bands and the SU_{sdg} (5) Limit of sdgIBM

The high resolution data on the γ-ray energy sequences in superdeformed (SD) bands of some nuclei (in mass A ~ 150 region) led recently to the discovery of rotational sequences in which states differing by four units of spin($\Delta L=4$) are systematically displaced by ~ 50eV with respect to those that lie half-way between them, indicating the role of hexdecupole collectivity in SD bands. This $\Delta L=4$ staggering at large angular momenta has been interpreted earlier to be arising due to the alignment of a hexadecupole phonon along the axis of rotation which results in Y_{44} deformation perturbing the prolate spheroidal deformation. This gives rise to fourth order axially symmetric terms like $[I^2_1 - I^2_2]^2$ in the rotational energy resulting in a C_4 symmetry bifurcation. The fact that Y_{44} deformation plays a crucial role in the occurence of $\Delta L=4$ staggering compels one to seek an explanation within the framework of sdgIBM model developed by us earlier. The energy formula for the GS band in the SU (5) limit of sdgIBM is given by $E(L) = \alpha L(L+1) + \beta \{(7L+8) - (-1)^{1/2} (2L+8)\}$; α and β are free parameters and L=0,2,4,..., . From this equation it is easy to see that the ground band in SU_{sdg} (5) limit exhibits complete $\Delta L= 4$ staggering. Thus SU_{sdg} (5) symmetry limit gives naturally the staggering but it over estimates the amount of staggering. Since a $K=0^+$ rotational band is well described by the (4N,0) representation of $SU_{sdg}(3)$ limit of sdgIBM, mixing calculations are carried

out by employing a $SU_{sdg}(3)$ and $SU_{sdg}(5)$ interpolating Hamiltonian. There is clear indication from the first calculations that the mixing calculations give the observed numbers. Thus the $\Delta L=4$ staggering in SD bands appear to indicate the presence of $SU_{sdg}(5)$ dynamical symmetry. Further investigations are in progress. This work is being carried out in collaboration with Y.D. Devi.

(V.K.B. Kota)

PARTICLES AND FIELDS

Hadronic Masses in the Open Flavours from Relativistic Harmonic Confinement Model (RHM)

The relativistic harmonic confinement model (RHM) with scalar plus vector potential of the form

$$V_{conf} = \tfrac{1}{2}(1 + \gamma_0) A^2 r^2 + B$$

where A and B are the free parameters for the confinement of quarks, has been found to be one of the most successful models to describe the hadronic properties and nucleon-nucleon interactions in a unified manner. We have now extended the RHM for computing hadron masses in the open flavours including light and heavy flavoured quarks.

The energy eigenvalues of the confined quarks are given by the expression:

$$E^2_n = m^2 + (2n+1)(E_n + m)^{1/2} A \, , \; n \geq 1$$

where $m = N + m_q$ and m is the current quark mass of the q-flavoured quark. We compute the masses of the hadrons by adding the individual contribution of the quark's intrinsic energy after correcting for spurious motion of the centre in the same way as used for the study of light baryonic masses. With the same RHM parameters, we compute the energies for the centre of mass of the spin 1/2 - spin 3/2 baryonic systems and the centre of mass of the scalar-vector mesonic systems in different flavour combinations. An overall agreement with the experimental values is obtained in the present model. We observe that for hadrons of mixed quark flavours the spurious motion of the centre may not be important if light to heavy quark mass ratio is less than 0.1. However, an exact fine tuning can be done only by incorporating the confined one-gluon-exchange potential between the quarks. This work was done in collaboration with P.C. Vinodkumar and V.M. Bannur.

(S.B. Khadkikar)

Pseudo Dirac Neutrinos

The conventional seesaw scheme employed for understanding the smallness of neutrino masses generally leads to masses which are hierarchical in generation space. It is shown that this need not always be true. Seesaw schemes with suitable global symmetry can lead to pseudo Dirac structure for the neutrino masses. Implications of this for the solar neutrino problem and neutrinoless double β decay are worked out.

(G. Datta and A.S. Joshipura)

Late Decaying τ Neutrino

The COBE observation on cosmic microwave background radiation seem to indicate that all the dark matter in the universe is not cold. It is pointed out that the simple cold dark matter scenario can be made consistent with the COBE results if the τ neutrino is massive and decays before the equality of matter and radiation. Detailed scheme which gives rise to such decay and which simultaneously solves the solar and atmospheric neutrino problems is proposed. This work was carried out in collaboration with J.W.F. Valle.

(A.S. Joshipura)

Neutrino Stability and the Left Right Symmetric Models

The left right symmetric models with parity broken around TeV scale contain τ neutrino with ~ MeV mass. This is required to be unstable in order to avoid conflict with the cosmological mass density. Conventional left right symmetric models do not contain massless majoron which is needed to cause rapid decay of massive neutrinos. Alternative schemes involving left right symmetry and majoron are proposed and their consequences are worked out in detail. This work was carried

out in collaboration with E. Akhmedov, S. Ranafone and J.W.F. Valle.

(A.S. Joshipura)

Novel R Parity Violation

The supersymmetric standard model is assumed to be invariant under discrete symmetry called R parity which distinguishes ordinary matter and their superpartners. Small violation of this symmetry would result in the mixing of these states. We point out that mixing of Higgs with the scalar partner of neutrino implied by very small violation of R parity can lead to large effects in the decay of Higgs. We determine the region of parameters in the minimal supersymmetric standard model for which the R parity violating decays of Higgs dominate over the conventional decays. This changes the Higgs phenomenology in a substantial manner. This work was done in collaboration with F. Campos, M. Jerano, J. Rosiek and J.W.F. Valle.

(A.S. Joshipura)

Quasi Goldstone Fermions and Neutrino Physics

Various direct and indirect experimental results on neutrino oscillations seem to require a sterile neutrino mixed with the ordinary neutrinos. We point out that light fermions present in supersymmetric theory with spontaneously broken global symmetry may play a role of these sterile states. Detailed scenarios are proposed which lead to a solution of the solar, atmospheric and the dark matter problem through this mechanism. This work was carried out in collaboration with E.J. Chun and A. Yu. Smirnov.

(A.S. Joshipura)

Effective Potential At Finite Temperature :A Variational Approach

We compute the effective potential for ϕ^4 theory with a variational ansatz for the ground state. The method essentially consists in optimising the basis at finite temperatures and a squeezed coherent state type construct for the ground state and is nonperturbative. The gap equation becomes identical to resuming an infinite series of daisy and super-daisy Feynman graphs of perturbation theory at finite temperature. The resulting effective potential turns out to be the same as obtained through composite operator formalism at finite temperature.

(Amruta Mishra and H. Mishra)

Macho Formation by the Gravitational Collapse of Wimps:

Sellars objects (MACHO's) in the mass range of 10^{-3} - 10^{-1} $M_{\odot}$ have been observed in the halo of our galaxy via their microlensing. These stellar objects do not have the colour and luminosity which is expected from such objects if they were composed of baryons. We propose that the primary constituent of MACHO's are weakly interacting massive particles (WIMP's) which are supposed to constitute the major fraction of dark matter. We evaluate the mass, radius, luminosity and colour (surface temperature) of such objects and show that it is consistent with the observed characteristics of MACHO's. This work was done in collaboration with P. Panda and S. Mishra.

(S. Mohanty)

Cerenkov Radiation by Neutrinos in a Supernova Core

Neutrinos with a magnetic dipole moment propagating in a medium with a velocity larger than the phase velocity of light emit photons by the Cerenkov process. The Cerenkov radiation is a helicity flip process via which a left-handed neutrino in a supernova core may change into a sterile right-handed one and free-stream out of the core. Assuming that the luminosity of the sterile right-handed neutrinos is less than 10^{53} ergs/sec gives an upper bound on the neutrino magnetic dipole moment $\mu_\nu < 5.8 \times 10^{-14}\ \mu_B$. This is two orders of magnitude more stringent than the previously established bounds on μ_ν from considerations of supernova cooling rate by right-handed neutrinos.

(S. Mohanty and M. K. Samal)

No Birefringence in Einstein's Gravity

Einstein's theory predicts that massive test particles with non-zero spin or angular momentum in an external gravitation field follow geodesics which depend upon the orientation of the spin-angular momentum. It has been claimed that such an effect also holds for photons, i.e., photons with different helicities follow different geodesics in the gravitational field of a rotating body. If such an effect were to exist it would result in a polarisation dependent deflection of light passing in the vicinity of the sun or a polarisation dependent time delay of pulsar signals . We show here that contrary to earlier claims , in Einstein's gravity there is no birefringence and photons follow null geodesics irrespective of polarisation. Thus if gravitational birefringence is ever observed experimentally then it would be a signal of new physics beyond Einstein's gravity.

(S. Mohanty and A.R. Prasanna)

Electric and Weak Dipole Couplings of Heavy Fermions

Since CP violation is not fully understood theoretically, it is worthwhile to look for new CP-violation phenomena. In particular, electric dipole coupling of fermions to the photon, and a generalization to the "weak" dipole coupling to the Z^0 , if they exist, would indicate CP violation. We have looked for effects of electric and weak dipole couplings of heavy fermions f in the process $e^+ e^- \rightarrow f\bar{f}$ followed by decay of f and $\bar{f}$.

(a) In the case of the τ lepton, the work on CP-odd correlations in the decay products has been extended to lower energies of the proposed tau-charm factories. In each case, the sensitivity to the dipole moments for a luminosity corresponding to 10^7 τ pairs is determined. It is found that longitudinal polarization of the electron beam can permit determination of the electric dipole moment as low as about 10^{-19} e cm for a centre-of-mass energy of 10.58 GeV. The work was done in collaboration with B. Ananthanarayan.

(b) In the case of the top quark, it was shown that in the measurement of correlations, longitudinal polarization of the electron beam can be put to use, firstly to improve the sensitivity to dipole moments, and secondly to make independent determinations of electric and weak dipole moments. Quantitative studies have been done for a proposed $e^+ e^-$ linear collider with centre-of-mass energy 500 GeV. This work was done in collaboration with F. Cuypers.

(c) Also in the case of top quark, several new asymmetries which are indicative of CP violation have been studied.These asymmetries depend on different linear combinations of the real and imaginary part of the electric and weak dipole moments of the top quark. Taken together, they can help to put stringent independent bounds on these moments at a future linear collider. The same studies were also carried out in the presence of beam polarization, and the qualitative and quantitative improvements as in (b) above were pointed out.

(P. Poulose and S.D. Rindani)

Study of CP-odd $\gamma\gamma Z$ and γZZ Couplings

If neutral gauge bosons γ and Z have anomalous trilinear couplings which violate CP, then they could give rise to observable effects in $e^+ e^- \rightarrow \gamma Z$, a process feasible at LEP200 at CERN in the near future. The simplest signal of such couplings would be the forward-backward asymmetry of the emitted photon. Quantitative feasibility studies have been made for LEP200 machine with centre-of-mass energy of 200 GeV and a future linear collider with centre-of-mass energy 500 GeV. This work was done in collaboration with D. Choudhury.

(S.D. Rindani)

Hadron Current-Current Correlation Functions in QCD Vacuum

Quantum chromodynamics is believed to be the theory of strong interactions. In the low energy sector, the theory is nonperturbative and the QCD vacuum is nontrivial. In an earlier work we have constructed a variational ansatz for the QCD vacuum with both quark and gluon condensates.

The current-current correlation functions form a rich set of observables to study the QCD vacuum. The correlators can be used to study the interquark interaction and its dependence on distance and, in fact, complement bound state hadron properties. We have studied such equal time, point-to-point correlation functions for spatially separated hadron currents with respect to our variational construction for the ground state of QCD. In each channel we associate the current with a physical hadron having quantum numbers identical to that of the current.

Given our variational ansatz, we make no further approximations in the evaluation of the correlators. With our calculations, the vector, axial and scalar channels show qualitative agreement with phenomenological results. The delta channel also follows the predicted curve, whereas, the pseudoscalar and nucleon channels show large departures. However, these two, when approximated by saturating with intermediate physical states agrees with the predicted behaviour.

We have shown that the quark propagation in our construction for the QCD vacuum is almost identical to that in the random instanton liquid model developed by Shuryak and collaborators. If one believes that the correlation functions are just the square (cube) for the meson (baryon) channels, then it is not clear why in the instanton model these correlators should agree remarkably well with phenomenological predictions, while in our model, they do not.

In view of these findings, it is not clear whether saturation of intermediate states in the evaluation of the correlator is sufficiently well justified. We therefore think that a unified treatment of correlation functions in all the channels is still not available.

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

Grand Unified Theories

Grand Unified Theories (GUTs) offer the possibility of a simple, but unified, description of strong and electroweak interactions. The unified groups do not only break down to $SU(3)_C \times SU(2)_L \times U(1)_Y$ at low energies, but do offer explanations to many puzzles of the Standard Model. An important class of GUTs are the left-right symmetric models where the Standard Models comes from a larger group with a $SU(3)_C \times SU(2)_L \times SU(2)_R \times U(1)_{B-L}$ symmetry. It was shown that the stringent bounds placed on the left-right symmetry breaking scale from a recent analysis of measurements at Large Electron Positron collider can be relaxed if effects of gravity is taken into account. Two loop corrections and threshold corrections which play an important role in these calculations were also evaluated. These works were done in collaboration with A. Datta and S. Pakvasa.

Another important issue in grand unified theories is the question of proton decay. This becomes highly interesting if baryon number is gauged in any GUTs. In SU(15) GUT this question has been studied (with P. Pal) and the role of global symmetries have been discussed.

(U. Sarkar)

Baryogenesis via Lepton Number Violation

One of the most important problems in particle physics and cosmology is the question of baryogenesis. The large baryon asymmetry observed today correspond to $\sim 3 \times 10^{-8}$ at early times. Sakharov proposed that it is possible for the universe to dynamically evolve a baryon asymmetry starting from an initially baryon symmetric state. This requires three basic ingredients: (a) Baryon number violation; (b) C and CP violation, and (c) these processes must not take place in thermal equilibrium. It is possible to satisfy all these criterion in grand unified theories (GUTs) at energies around 10^{15} GeV. However, it has been shown that during the electroweak phase transition at around 10^2 GeV, anomalous baryon number violating processes may take place in equilibrium in the presence of the sphaleron fields. This will erase any baryon asymmetry generated in the GUT era. We have pointed out that in left-right symmetric models there are C and CP violating out-of-equilibrium lepton number violation at energies around the right handed symmetry breaking scale, which can then generate the required amount of baryon

asymmetry during the electroweak phase transition. This work was carried out in collaboration with P.O'Donnel.

(U. Sarkar)

Renormalization Group Improved Thermal Coupling Constant in an External Field

Starting from renormalised effective Lagrangian, in the presence of an external Chromo-Electric field at finite temperature, the expression for thermal coupling constant as a function of temperature and external field is derived using finite temperature two parameter renormalisation group equation. For some values of the parameters, the coupling constant is seen to be approaching a value ~ unity. The implication of this result from the point of view of Relativistic Heavy Ion Collision for production of Quark Gluon Plasma and the observed $e^+ e^-$ peaks in the Heavy Ion Experiments in GSI Darmstadt is indicated.

(A.K. Ganguly)

Thermal Effective Lagrangian with Finite Chemical Potential in an External Field

Thermal Effective Lagrangian with finite chemical potential in an external field is computed. We have evaluated the decay rate of this external field using standard techniques of finite temperature field theory. At high temperature the rate is proportional to T^2 and has a value higher than the rate at $T = 0$. It is also observed that the rate of pair production decreases as one moves away from the Lorentz contracted nuclei towards the centre in the cm coordinate system. Finite chemical potential is seen to counter the effect of the external field.

(A.K.Ganguly)

$Q\bar{Q}$ *Tunnelling in a Thermal Flux Tube with Finite Radius*

Decay rate of an external electric field is computed at finite temperature using imaginary time formalism of Matsubara. Other than the usual features of high temperature field theory, it is shown here that the finite transverse size introduces an effective mass for the particles. As a result, the decay rate of the electric field gets suppressed. Following an earlier work on the possibility of existence of strong Chromo-Electric flux tubes, in equilibrium with QGP, formed in relativistic heavy ion collision experiments, we try to estimate here their thermal decay rate, taking the finite extent of the system into account. This work was done in collaboration with S. Sengupta.

(A.K. Ganguly)

Bloch-Nordsieck Thermometers : One Loop Exponentiation in Finite QED

In a real-time finite temperature field theory, the distribution of the summed momenta of soft photon radiation associated with a hard scattering of an external charged particle in a heat-bath is constructed. Infrared singularities cancel between real and virtual processes. Every cumulant of the total radiated momentum is the sum of a zero-temperature and a temperature dependent part. A fully covariant analysis of the second cumulant by defining certain Lorentz invariant form factors is performed. We investigate these in detail and identify the effects of collinear divergences. Our main result is that there are no kinematic differences between the finite temperature resummation and the well-known results at zero temperature. This work was done in collaboration with S. Gupta, V. Ravindran, R.M.Godbole, D.Indumathi and P. Mathews.

(A.K. Ganguly)

Screening Of The External Chromo-Electric Field In A Thermal Bath

The exact response of thermal vaccum to an external field was computed and the screening length of the external field in the plasma was obtained. A linearised analysis of the problem was performed and found to be qualitatively in agreement with the standard perturbative results. But the exact numerical analysis shows that the potential screens much faster than what is estimated perturbatively.

(A.K. Ganguly and J.C. Parikh)

Facilities at PRL

COMPUTER CENTRE

The usage of high-end workstations (five IBM RS. 6000/580 and one HP 9000/735) installed last year has been gradually picking up through out this year. The users have been extensively using the powerful and versatile mathematical and graphics packages such as IMSE with EG, MATHEMATICA, AVS etc. on these machines. This year also marks the complete changeover from the old computer system DEC 1091 to new computer systems. Consequently the operation of Computer System DEC 1091 has been permanently discontinued.

As expected, the six powerful workstations with DP LINPACK rating of about 40 MELOPS form the mainstay of compute-intensive and visualization jobs of the users. These machines which are on the campus-wide local-area Ethernet network are running twenty four hours a day. As a result a user sitting at any remote, simple pc-based mode can have access to the power of these machines at any time of the day. Thus the users have been experiencing a new computing environment not available so far.

The following additions have been made this year to provide better facilities and more convenience to the users.

- ★ A cartridge tape drive (capacity 1.2 GB) has been procured to have a common and inexpensive medium for transporting data and software.
- ★ A new software package IDL (Interactive Data Language) has been installed on the workstation prlts1 with six-user licence. The IDL provides a very powerful array-oriented language with built-in graphics, mathematical and statistical functions
- ★ A PC-based neural network software package called 'NEURALWARE' has been made avialable for the development of application using different neural network architectures and algorithms.
- ★ A large number of hard-copy manuals pertaining to operating system, languages, graphic primitives and networking has been procured.

Research and Development

Research and Development work has been carried out in modelling and simulation in atmospheric physics, time series analysis using non-linear dynamics and neural network, numerical methods, statistics and operations research. The other activities of the centre include consultation to users, teaching to research scholars of PRL and space science students of Gujarat University, and conducting courses for the new systems and software packages.

LIBRARY

Collection

The PRL library subscribes to 197 scientific and technical journals. A large number of scientific reports, data, maps, etc. are also received. 241 books were added to the library.

Services

Over 80,000 photocopies were made according to requests received from PRL personnel, from other libraries and research scholars outside PRL.

Requests were received for obtaining about 349 publications from other libraries on Inter-Library-Loan. Most of these publications were obtained on loan for our readers. About 300 publications were loaned by us to other libraries.

During the year, 6533 books and journals were issued. Several queries were received for providing factual information, locating addresses, giving biodata, preparing bibliographies etc.

Library Automation

A brochure has been prepared on *Introducing OPAC* and the Online Public Access Catalog has been started, to enable remote access of the library database.

The identification numbers of all the library members have been barcoded for circulation. Computerised circulation enables the users to put a claim for issued material, check their issue records etc.

Data comprising of the complete details of 24,000 bound volumes of journals was inputted for circulation purpose.

Library has acquired the Physics Abstracts Database published by INSPEC on CD-ROM for the years 1992-1995. This database is very useful for both current and retrospective search.

ELECTRONICS LABORATORY

Artificial Neural Networks (ANN)

In the computational learning methods connectionism or more popularly known as neural network or parallel distributed processing has gained considerable importance and attention of researchers. We have been working on software simulation and hardware development for different neuron types and configuration for network.

The multilayered type Neural Network is successfully implemented in Digital Signal Processors and Microcontrollers both for digital and analog input/output functions. A new neuron activation function is developed which works with integer arithmatics. The algorithm uses dynamic activation function by reinforcing the activation function co-efficient of the type

$$Yk = Yb + \frac{Yb * Xk}{Gk + abs(Xk)} \qquad (1)$$

In the above equation Yb is constant equal to half the dynamic range of Yk. Gk is the coefficient, which decides the slope of the activation function. Gk is also reinforced during training. This algorithm is implemented in DSP and microcontroller as a stand alone real time neuro controller module. This type of module can be used in real life for real time applications like process control, pattern recognition, modelling etc.

Computer Networking

Electronics Laboratory contributed significantly to establish campus wide heterogeneous Local Area Network based on thick and thin ethernet and TCP/IP protocol to provide connectivity to all the computers on the campus. The TCP/IP protocol chosen will provide a smooth integration of PRL LAN into Internet.

Mass Spectrometer

A prototype of the Fourier Transform Ion Cyclotron Resonance Mass Spectrometer is being developed. The basic vacuum system has been set up to give pressure of the order of 10^{-9} torr with the help of rotary and sputter ion pump. The ion-source and trap cell are being developed. A proto type ion source developed provides an ionic current of the order of 2 ma. It is being modified to increase the efficiency. A high voltage power supply 5kv @ 10mA is developed for the sputter ion pump.

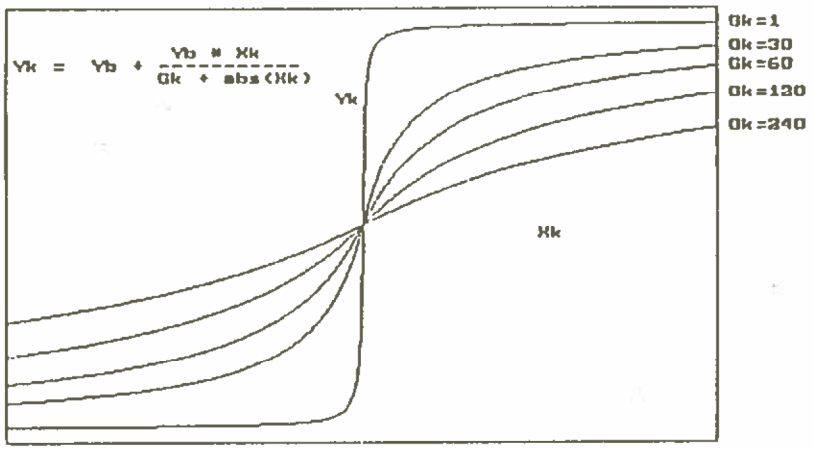


Fig-1 : Plot of the activation function Yk=Yb+Yb Xk/(Gk +abs(Xk)) for different values of Gk*

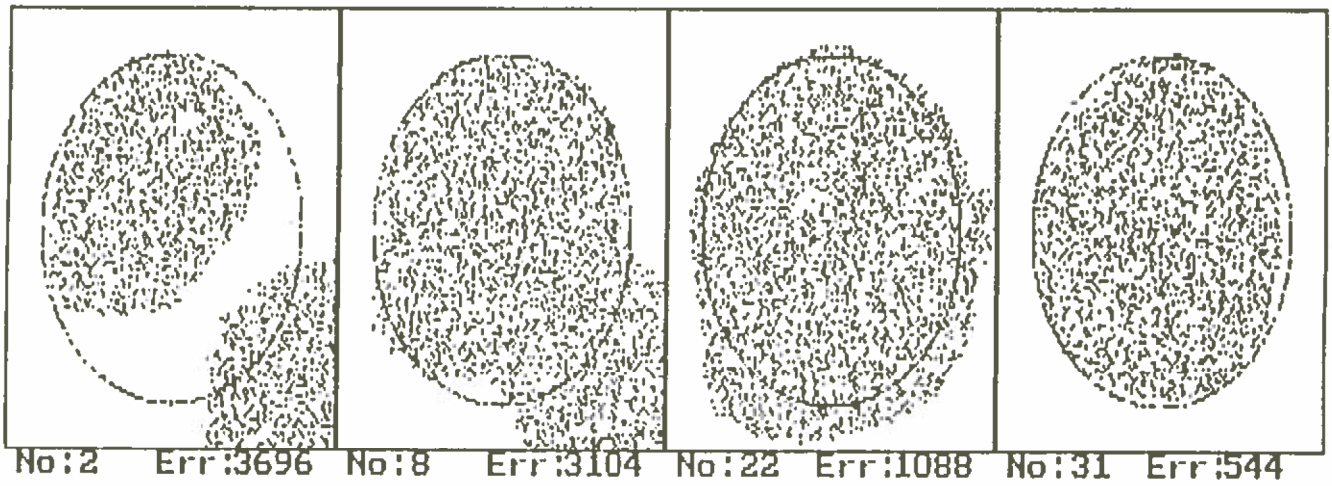


Fig-2 Output of Network at different iterations. The network is having two analog input and one binary output using activation function of equation -1. The network is trained to map a circle in 8 x 8 image plane.

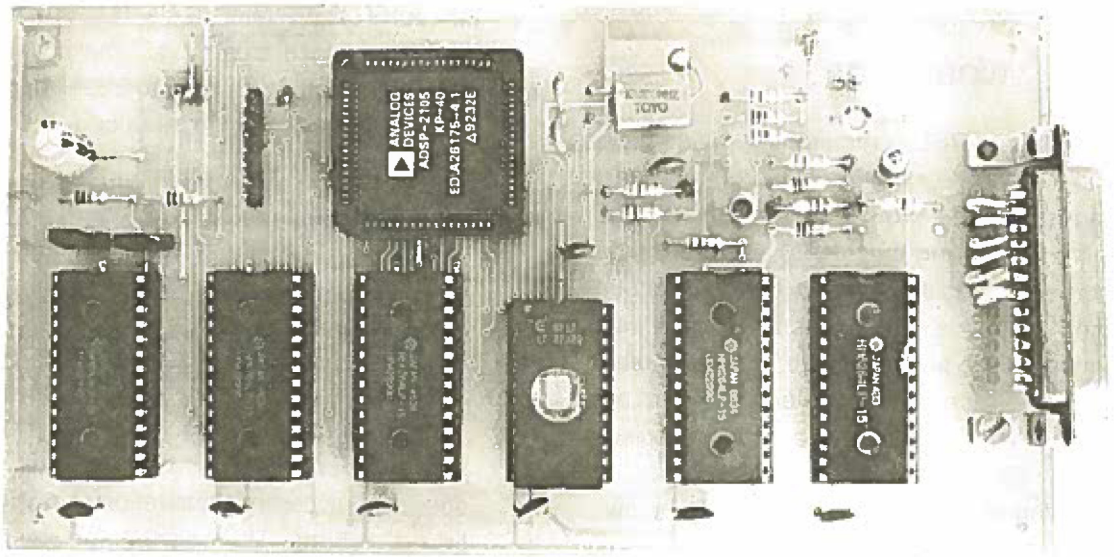


Fig-3 ADSP 2105, Digital Signal Processor based on Neuro controller card developed in Electronics Laboratory , PRL.

Training Activities

Number of students of B.E. (Electronics and Computer Engineering) and MCA did their project work in Electronics Laboratory. Following are the list of projects undertaken and completed by students.

- ★ Hand Written Character Recognition.
- ★ Face Maker.
- ★ ADSP-2105 Digital Signal Processor Development System.
- ★ Speaker Dependent Isolated Word Speech Recognition System.
- ★ Implementation of Feed Forward Neural Network on the TMS 320C25 Digital Signal Processor.
- ★ 8096 Micro Controller Development System.
- ★ Implementation of Feed Forward Neural Network using 8051 micro controllers.
- ★ X-25 and X-400 protocol implementation (MCA student project)

WORKSHOP

The Workshop at PRL continued to provide major technical support to all the experimental programmes at PRL. The facilities in the Workshop range from lathe, milling, shaping and drilling machines, profile projector system, argon gas welding sytems for high vacuum chambers/joint. A plasma cutting machine for cutting of non-ferrous materials is also available. The Workshop extension at Thaltej recently completed two years and was upgraded with the addition of an HMT precision Lathe machine. Some of the important jobs accomplished by the Workshop during 1995 are listed below:

- ★ Design and fabrication of the mechanical systems for three all sky mirror scanning systems to provide a universal motion without any backlash error. This involved machining/fabrication of large gear driving of 242 mm in diameter and having 240 teeth of one module and driven gear at 40 teeth of same module thrust bearing etc. The system operated successfully in Antarctica, as also in day-glow and night-time Fabry-Perot experiments.
- ★ Fabrication of a pressure scanned Fabry-Perot system involving development of a 100mm diameter 100mm long brass chamber with glass windows. In this job, filter holders with Peltier Cooling assembly was made for temperature stabilization of the filters.
- ★ Fabrication of laser-produced plasma scattering chamber. This involved fabrication of a large vaccum stainless steel chamber capable of holding high vacuum and achieving a tolerance of 1 μm for folding mirror mount and Wilson type vacuum sealings.
- ★ Fabrication of corers for sampling deep sea sediments, from depths ranging from 800m to 3000m below sea level. The corer fabrication consisted of having a 3000mm black MS pipe with structural support and couplers, overflow valves of nylon and PVC and a non-return valve made using a thin sheeet of spring stainless steel sheet 0.35mm gauge and a stainless steel ring. The cover was used successfully during an Indian Ocean expedition and several 2m cores could be raised.
- ★ Fabrication of a system for studies on dusty plasmas. The system involved fabrication of a stainless steel vacuum chamber (150cm X 27mm dia) and necessitated fabrication of stainless steel chamber, flanges with a tolerance limit of 1- 5 μm.
- ★ Fabrication of Langmuir Probes for ionospheric electron density studies. The probe had a ogive-shape and consisted of 25 components of stainless steel, brass, ceramic and teflon all with a tolerance limit of 1- 5μm. The ogive shape was made on a lathe machine and the complete sensor had a grinding finish of - 0.025μm to 1.6μm.
- ★ Fabrication of an equilibrator system to equilibrate seawater with pure helium or nitrogen. The system fabrication consisted of a mechanical arrangement

of platform with mixing chamber. The platform reciprocates in a precise machined guides.

★ Fabrication of Coleostat system for studies on the forthcoming solar eclipse. The system will provide an accurate drive mechanism for the optical assembly to track the sun with 1 rev in 48 hours enabling a continuous observation and photography during the 48 sec of totality.

★ Fabrication of Hartman Screen to establish the zonal accuracy of the recently installed 48" dia IR telescope at Mt.Abu. This job involved drilling of 96 holes at precise location with a tolerance limit of ±0.5mm.

Additionally, Workshop carried out several jobs relating to precision machinery, optical mounting, fabrication of amplifier boxes for IPS system, painting etc. Often the jobs were carried out in field conditions with limited facilities. The workshop also repaired a lapping machine for the glass blowing section thereby saving substantial costs needed for its replacement that would have been otherwise necessary.

ENGINEERING SERVICES

The Engineering services render all technical services pertaining to civil engineering works and related building and laboratory services such as air conditioning, electrical, elevators, inter communication system, public health etc. right from the land acquisition to maintenance and replacement of all buildings and campuses (residential and non-residential and its related technical services). The service is also performing all the functions of Civil Engineering and Engineering Maintenance Division - architectural planning, designing, estimating and execution of various building projects including all related services, landscaping, horticultural development and maintenance and upkeepment, interiors and furnishings of buildings and structures of all the campuses - PRL Main campus, Thaltej campus, Gurushikhar observatory, Udaipur Solar Observatory and staff colony. Site preparation works for installation of sophisticated research equipments by meeting with their clean room specifications and other special requirements, are also executed.

During the year, following works have been undertaken:

★ Construction of Optical Aeronomy Laboratory building to house the air glow experiments and the 1 metre Laser telescope of Gurushikhar campus

★ Drilling water supply tube well in Thaltej Campus

★ Extension to canteen in Thaltej Campus

★ Site preparation works for: i. Foucault's Pendulum in Library Block, ii. Mass Spectrometry Laboratory in Main Building and iii. ICP Spectrophotometer in Chemistry Laboratory Building.

Honorary Fellows at PRL

Honorary Fellows

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

Academic Faculty of PRL

Name	Designation	Specialisation	Academic Qualification
Prof R.K. Varma FNA, FASc, FNASc	Director	Plasma Physics, Classical and Quantum Mechanics	Ph D California Univ. (UCSD), USA (1965)
Prof J C Parikh FNASc	Sr Professor II	Particle Physics	PhD Chicago Univ. (1962)
Prof B L K Somayajulu FNA, FASc, FNASc	Sr Professor I	Geochemistry and Oceanography	Ph D TIFR Bombay Univ. (1970)
Prof N Bhandari FASc, FNASc	Sr Professor I	Planetary Physics	Ph D TIFR Bombay Univ. (1967)
Prof J N Desai FNASc	Sr Professor I	Expt. High Resolution Spectroscopy and Light Scattering	Ph D Gujarat College, Gujarat Univ. (1964)
Prof A C Das	Sr Professor I	Theoretical Plasma Physics, Space Plasmas	Ph D Imperial College London Univ. (1968)
Prof S B Khadkikar	Sr Professor I	Particle Physics	Ph D TIFR Bombay Univ. (1970)
Prof S Krishnaswami FNA, FASc, FNASc	Sr Professor I	Aqueous Geochemistry and Nuclear Oceanography	Ph D TIFR Bombay Univ. (1974)
Prof A R Prasanna	Professor	General Relativity and Astrophysics	Ph D Poona Univ. (1970)
Prof M R Deshpande	Professor	Astronomy and Astrophysics and Space Sciences	Ph D PRL Gujarat Univ. (1968)
Prof Vijay Kumar	Professor	Experimental Atomic and Molecular Physics	Ph D Adelaide Univ. Australia (1970)
Prof D P Dewangan	Professor	Atomic and Molecular Physics	Ph D Calcutta Univ. (1973)
Prof J N Goswami FASc	Professor	Solar System Studies (Pre - Solar Processes)	Ph D PRL Gujarat Univ. (1978)
Dr A Bhatnagar FNASc	Scientist G / Director USO	Solar Physics	Ph D Agra Univ. (1965)
Dr V B Sheorey	Asso Professor	Theoretical Atomic Physics and Nonlinear Dynamics	Ph D Univ. College, London Univ. (1968)
Dr A S Joshipura	Asso Professor	Particle Physics	Ph D Bombay Univ. (1988)

Name	Designation	Specialisation	Academic Qualification
Dr S D Rindani	Asso Professor	Particle Physics	Ph D IIT, Bombay (1976)
Dr A K Singhvi	Asso Professor	Palaeoclimatology and Geochronology	Ph D IIT, Kharagpur (1975)
Dr D K Chakrabarty	Asso Professor	Ion and Neutral Chemistry of Earth's Atmosphere	Ph D NPL Delhi Univ. (1973)
Dr Harish Chandra	Asso Professor	Ionospheric Studies and Dynamics of Middle Atmosphere	Ph D PRL Gujarat Univ. (1970)
Dr S K Bhattacharya FASc	Asso Professor	Isotope Geochemistry	Ph D PRL Gujarat Univ.(1980)
Dr T R Venkatesan	Asso Professor	Geochronology	Ph D Minnesota Univ. (1976)
Dr V K B Kota	Asso Professor	Nuclear Physics	Ph D Andhra Univ. (1977)
Dr B G A Rao	Asso Professor	Spectroscopic Diagnostic in Astrophysical Plasmas	Ph D PRL Gujarat Univ. (1978)
Dr S P Gupta	Asso Professor	Electrodynamics of Middle Atmosphere	Ph D PRL Gujarat Univ. (1971)
Dr R Sridharan FASc	Asso Professor	Upper Atmospheric and Ionospheric Physics	Ph D PRL Gujarat Univ. (1984)
Dr P Sharma	Reader	Geophysics and Hydrology	Ph D PRL Gujarat Univ. (1977)
Dr U C Joshi	Reader	Star Formation, AGNS and Comets	Ph D Kumaun Univ. (1981)
Dr P N Shukla	Reader	Geochemistry	Ph D IIT, Kanpur (1977)
Dr N M Ashok	Reader	Infrared Observations	Ph D PRL Gujarat Univ. (1983)
Dr T Chandrasekhar	Reader	Optical & Infrared Astronomy	Ph D PRL Gujarat Univ.(1982)
Dr B R Sitaram	Reader	Classical Mechanics, Mathematical Physics, Computer Simulations	Ph D Delhi Univ. (1982)

Name	Designation	Specialisation	Academic Qualification
Dr N Nagesha Rao	Reader	Theoretical Plasma Physics	Ph D PRL Gujarat Univ. (1982)
Dr Shyam Lal	Reader	Atmospheric Chemistry of Trace Gases	Ph D PRL Gujarat Univ. (1982)
Dr R Ramesh	Reader	Isotope Geochemistry	Ph D PRL Gujarat Univ. (1984)
Dr H S S Sinha	Reader	Upper Atmcspheric and Ionospheric Studies	Ph D PRL Gujarat Univ. (1977)
Dr A Jayaraman	Reader	Atmospheric Aerosols and Radiative Studies	Ph D PRL Gujarat Univ. (1985)
Dr Hari Om Vats	Reader	Ionospheric Physics and Radio Astrophysics	Ph D PRL Gujarat Univ. (1979)
Dr M M Sarin	Reader	Geochemistry and Oceanography	Ph D PRL Gujarat Univ. (1985)
Dr S V S Murty	Reader	Isotope Cosmochemistry	Ph D IIT, Kanpur (1981)
Dr Utpal G Sarkar	Reader	Particle Physics	Ph D Calcutta Univ. (1984)
Dr A K Ambastha	Reader	Solar Plasma Physics	Ph D PRL Gujarat Univ. (1981)
Dr G Subramaniam	Fellow	Cosmic Ray Physics	Ph D PRL Gujarat Univ. (1965)
Dr Sushil Kumar Gupta	Scientist F	Geophysics, Hydrology	Ph D IIT, Bombay (1974)
Dr R K Pant	Scientist F	Geomorphology	Ph D Banaras Univ. (1977)
Dr V N Nijampurkar	Scientist F	Glaciology	Ph D TIFR Bombay Univ. (1977)
Dr A M Punithavelu	Scientist E	Experimental Plasma Physics	Ph D Patrice Lumumba Univ., Moscow (1975)
Dr (Miss) S L Kusumgar	Scientist E	Palaeoclimatology, Chronology	Ph D PRL Bombay Univ. (1980)
Dr G D Vyas	Scientist E	Upper Atmospheric and Ionospheric Studies	Ph D PRL Gujarat Univ. (1980)

Name	Designation	Specialisation	Academic Qualification
Dr Sai K Iyer	Scientist D	Large Scale Structure, General Relativity	Ph D Washington Univ. USA. (1987)
Dr D P K Banerjee	Scientist D	Astronomy & Astrophysics, High Resolution Spectroscopy	Ph D PRL Gujarat Univ. (1991)
Dr K P Subramanian	Scientist D	Experimental Atomic and Molecular Physics	Ph D PRL Gujarat Univ. (1987)
Dr Kanchan Pande	Scientist D	Geology, Geochronology	Ph D PRL Gujarat Univ. (1990)
Dr Syed Aftab Haider	Scientist D	Planetary and Cometary Atmospheres	Ph D Banaras Univ. (1984)
Dr P Janardhan	Scientist D	Radio Astrophysics	Ph D PRL Gujarat Univ. (1992)
Mr I A Prajapati	Scientist D	Experimental Atomic and Molecular Physics	M.Sc., Gujarat Univ. (1981)
Mr R Narayanan	Scientist D	Optical Studies of Ionosphere	M.Sc., American College Madurai (1979)
Dr R Sekar	Scientist D	Optical Studies of Ionosphere	Ph D PRL Gujarat Univ. (1991)
Dr J R Trivedi	Scientist D	Geochronology	Ph D PRL Gujarat Univ. (1991)
Dr Subhendra Mohanty	Scientist D	Astroparticle Physics	Ph D Wisconsin Univ. (1989)
Dr Debi Prasad	Scientist D	Solar Cometary Physics	Ph D PRL Gujarat Univ. (1990)
Dr S.C. Tripathy	Scientist D	Solar Physics	Ph D PRL Gujarat Univ. (1993)
Dr. Rajmal Jain	Scientist D	Solar Physics	Ph D PRL Gujarat Univ. (1983)

New Director

New Director

Prof. R.K. Varma Retires as Director

Prof. Ram Kumar Varma, retired after a distinguished service on March 31, 1995 as Director, PRL. He will, however continue to serve PRL as an Emeritus Professor.

Prof. Varma joined the laboratory as Fellow in 1968 and took charge as Director on June 1, 1987. He has been actively associated with the various activities of the laboratory since then.

Prof. Varma has worked on a number of different topics in plasma physics and astrophysics, including the theory of mirror plasmas, tokamak plasmas, solitons in plasmas of various kinds, plasma neutral gas interaction, spiral structure of galaxies, galactic magnetic fields (a dynamical theory) etc. However, he had been working exhaustively on two areas which represent his major thrust and achievement. One of them is his work on the mirror machine plasmas and the other which is both theoretical and experimental pertains to the properties of the motion of charged particles in a magnetic field. He has discovered analogs of quantized solutions in classical domain.

Under Prof. Varma's leadership the scientific disciplines were organised to focus the laboratory's scientific goals. He encouraged team work in order to produce science with lasting impact. In addition to his scientific commitments, Prof. Varma was always concerned about the social environment and the interpersonal relationship amongst the members of the PRL family. Under his leadership the atmosphere was extremely cordial leading to the growth of science at PRL. The PRL campus was considerably improved to provide a better working environment. He took special interest in the popularization of science and in projecting the activities of PRL to public at large.

Prof. Varma is a Fellow of all the three Science Academies of India and Astronautical Society of India. He is a member of International Astronomical Union and Indian Astronomical Society and life member of Indian Physics Association and Plasma Science Society of India. He is actively connected with many institutes in India as a member of their Governing Bodies. He has also been associated with the International Centre for Theoretical Physics, Trieste.

We are happy that Professor Varma will continue to be with us and we will continue to have the benefit of his experience, skill and wisdom.

Prof. G.S. Agarwal Takes Over As Director

Prof. Girish S. Agarwal, Professor, School of Physics, Hyderabad University has taken charge as Director of the Physical Research Laboratory, Ahmedabad on April 18, 1995. His major research interest is on various branches of Optical and Laser Physics; non equilibrium Statistical Mechanics, Stochastic Processes and Foundations of Quantum Mechanics.

Professor Agarwal is an outstanding theoretical physicist who has been recognized nationally and internationally for his scientific work. He has won many awards from international societies like Optical Society of America, American Physical Society, Third World Academy of Science. He is the winner of S.S. Bhatnagar award, Meghnad Saha award, Goyal Prize and is a Fellow of all the three Science Academies of India.

PHYSICAL RESEARCH LABORATORY

Ahmedabad - 380 009

Audited Statement of Accounts

as on 31 March 1995

SHAH & NAGORI

CHARTERED ACCOUNTANTS

PHYSICAL RESEARCH LABORATORY

AHMEDABAD 380 009

Trust Regn. No.E/1371/Ahmedabad

AUDITOR'S REPORT

We have audited the Accounts of the above referred Trust for the year ended 31st March, 1995 and beg to report as under :

(1) That the accounts are maintained regularly and in accordance with the provisions of the Act, and the Rules.

(2) That receipts and disbursements are properly and correctly shown in the account.

(3) That the cash balance and vouchers were in the custody of the cashier on the date of the audit and were in agreement with the accounts.

(4) That books, deeds, accounts, vouchers and other documents and records required by us were produced before us.

(5) That an inventory, certified by the Registrar of the movables of the Trust has been maintained. However, Physical Verification is not carried out for both movable and immovable assets.

(6) That the Accounts Officer, Shri G.N.Nagori appeared before us and furnished the necessary information required by us.

(7) That no property of fund of the Trust were applied for any objects or purposes other than the objects or purposes of the Trust.

(8) That the amounts outstanding for more than one year are Rs.8,41,913/- (including doubtful Rs.6,06,970/-) and the amount written-off are Rs.1,41,419/-.

(9) That tenders were invited for repairs or construction as the expenditure involved did exceed Rs.5,000/-.

(10) That no money of Public Trust has been invested contrary to the provisions of Section 35.

(11) That no alienations of immovable property have been made contrary to the provisions of Section 36.

(12) We have further to report that :

(i) The immovable and movable properties are acquired out of Central Government grants and hence no provision is made for the depreciation.

(ii) Refer our Separate observation letter of even date.

Place : AHMEDABAD

Date : 14-11-1995

M/S SHAH & NAGORI

CHARTERED ACCOUNTANTS

SHAH & NAGORI
Chartered Accountants

PHYSICAL RESEARCH LABORATORY
Ahmedabad 380009
Trust Regn. No.E/1371/Ahmedabad

BALANCE SHEET as at 31st March, 1995

FUNDS & LIABILITIES	Rupees	Rupees	PROPERTY & ASSETS	Rupees	Rupees
TRUST FUND CORPUS			IMMOVABLE PROPERTIES		
Grant and contribution		26,90,61,594	(AT COST)		3,78,21,658
OTHER EARMARKED FUNDS			INVESTMENTS (AT COST)		1,67,72,500
Depreciatin Fund	----		MOVABLE PROPERTIES		
Reserve Fund	----		(AT COST)		
Any Other Fund	16,44,800	16,44,800	Furniture, Fixtures, Equipments		
LOANS (SECURED OR UNSECURED)			Dead Stock, Vehicles,		
From Trustees	----		Books & Journals	19,97,87,899	
From Others	----	----	Stock of Stores (At Cost)	8,91,669	
PROJECTS BALANCES		98.42,684	Stock of Medicine (At Cost)	33,812	
LIABILITIES			(As per inventory certified		
For Expenses	4,67,341		by the management)		20,07,13,380
For Materials & Contracts	28,03,559		LOANS (UNSECURED)		
Miscellaneous Liabilities	17,11,128		Staff Members		
Other Deposits	1,48,435		Vehicle/Computer loan (including		
Recoverable P.F.Contribution	68,73,843	1,20,04,306	accrued interest Rs.7,01,282)	21,54,878	
			House building advance		
			(including accrued interest		
			Rs.47,56,180)	1,19,67,394	1,41,22,272
			SUNDRY DEBTORS		35,927
			(Including Rs.7,624 outstanding		
			for more than one year)		
TOTAL C/F Rs .=		29,25,53,384	TOTAL C/F Rs. =		26,94,65,737

FUNDS & LIABILITIES	Rupees	Rupees	PROPERTY & ASSETS	Rupees	Rupees
	TOTAL B/F Rs. =	29,25,53,384		TOTAL B/F Rs.	26,94,65,737
			ADVANCES		
			To Employees (including Rs12,368 more than one year)	7,46,031	
			To Contractors & Suppliers (Including Rs.7,62,574 for more than one year and Rs.6,06,970 considered doubtful)	33,91,371	
			To Other Projects		
			Projects Balances (Including Rs.35,650 for more than one year)	2,55,297	
			To Others (Including Rs.3,91,959 as deposit with others) (Rs.23,697 for more than one year)	20,00,994	
			To Civil Engineering Division	5,29,293	69,22,986
			INCOME OUTSTANDING		
			AES Grant Receivable	10,530	-
			KEF Grant Receivable	40.000	
			PRL EMPLOYEES PROVIDENT FUND	68,73,843	69,24,373
			CASH & BANK BALANCES		58,57,665
			INCOME & EXPENDITURE ACCOUNT		
			Balance as per last Balance Sheet Dr	8,61,222	
			Add : Deficit as per INC & EXP A/c	25,21,401	33,82,623
	TOTAL Rs. =	29,25,53,384		TOTAL Rs.=	29,25,53,384

The above Balance Sheet to the best of our belief contains a true accounts of Funds & Liabilities and of the Property &/ Assets of the Trust.

As per our report of even date

Shah & Nagori G.N.Nagori Dinesh Patel

Place : Ahmedabad
Dated : 14th Nov. 1995

Shah & Nagori
chartered Accountants

G.N.Nagori
Accounts Officer
PRL

Dinesh Patel
Secretary
PRL Council

SHAH & NAGORI
Chartered Accountants

PHYSICAL RESEARCH LABORATORY
Ahmedabad 380009
Trust Regn. No.E/1371/Ahmedabad

INCOME & EXPENDITURE ACCOUNTS for the year ended on 31st March 1995

EXPENDITURE	Rupees	Rupees	INCOME	Rupees	Rupees
EXPENDITURE IN RESPECT OF PROPERTIES			RENT (Accrued/Realised) :		
Rates, Taxes & Cesses	2,19,835		Realised	2,71,506	2,71,506
Repairs & Maintenance	38,40,531		INTEREST (Accrued/Realised):		
Salaries	----		On Security	----	
Insurance	----		On Loan : Vehicle/Computer Loan	1,89,287	
Depreciation	----		House Building Loan	7,02,304	
Other Expenses	----	40,60,366	on Miscellaneous	2,075	
ESTABLISHMENT EXPENSES :			On Bank Accounts	14,61,105	23,54,771
Remuneration (in case of Math to the Head of a Math, including his household expenses if any)		----	DONATION (In cash or kind) :		----
LEGAL EXPENSES :		32,490	GRANTS :		7,92,90,000
AUDIT FEES			INCOME FROM OTHER SOURCES :		
Statutory Audit Fees		55,000	In details as far as possible		
Contribution and fees :		----	Computer other use service etc.	----	
AMOUNT WRITTEN OFF :			Miscellaneous Income (Sale of scrap, Liquid Nitrogen job work income etc.)	94,649	
(a) Bad Debts & Store (Net)	3,791		Administrative expenses recovery	88,839	1,83,488
(b) Loan Scholarship	----		Sale of Assets		92,543
(c) Irrecoverable Rent	----		Provident Fund Contribution Received back from PRL Employee's Provident Fund Trust (on A/C)		10,00,000
(d) Other Items	----		Transferred from DOS non recurring Capital Grant		46,53,597
(e) Irrecoverable Proj. Balance W/O	1,36,802	1,40,593	Deficit carried to Balance Sheet		25,21,401
MISCELLANEOUS EXPENSES :		----			
DEPRECIATION :		----			
AMOUNT TRANSFERRED TO RESERVE FUND OR SPECIFIC FUND IN BALANCE SHEET :					
To DOS non-recurring capital grant for addition to movable properties (furniture, fixtures, dead stock, library Books & Journals)	61,80,737				
To House Building Advance Grant (Including Interest Rs.7,02,304)	13,02,304				
To Vehicle/Computer Advance Grant (including Interest Rs.1,89,287)	9,89,287	84,72,328			
	TOTAL C/F Rs. =	1,27,60,777		TOTAL C/F Rs. =	9,03,67,306

EXPENDITURE	Rupees	Rupees	INCOME	Rupees	Rupees
	TOTAL B/F Rs. =	1,27,60,777		TOTAL B/F Rs. =	9,03,67,306
EXPENDITURE ON OBJECTS OF TRUST :					
(a) Religious	----				
(b) Educational & Research	7,75,72,480				
(c) Medical Relief	----				
(d) Relief of Poverties	----				
(e) Other Charitable object	----	7,75,72,480			
Previous Year Expenditure		34,049			
	Total Rs. =	9,03,67,306		Total Rs. =	9,03,67,306

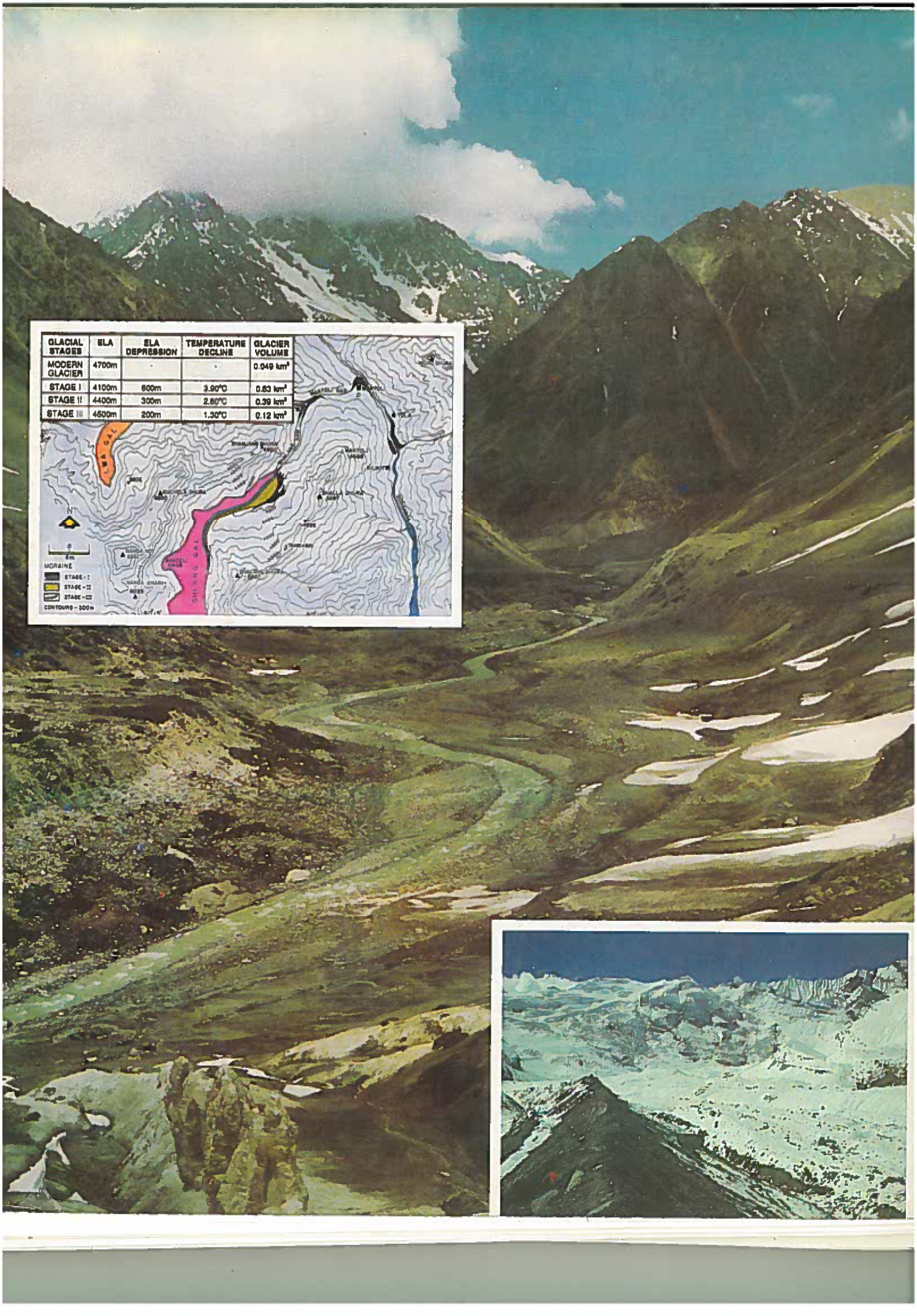
As per our report of even date

Place : Ahmedabad
Dated : 14th Nov. 1995

Shah & Nagori
Chartered Accountants

G.N.Nagori
Accounts Officer
PRL

Dinesh Patel
Secretary
PRL Council



GLACIAL STAGES	ELA	ELA DEPRESSION	TEMPERATURE DECLINE	GLACIER VOLUME
MODERN GLACIER	4700m	-	-	0.049 km³
STAGE I	4100m	600m	3.90°C	0.83 km³
STAGE II	4400m	300m	2.60°C	0.39 km³
STAGE III	4600m	200m	1.30°C	0.12 km³