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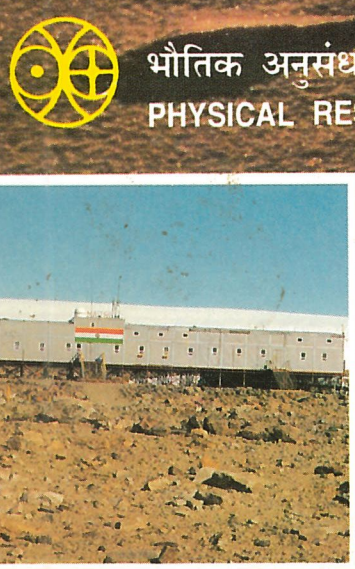

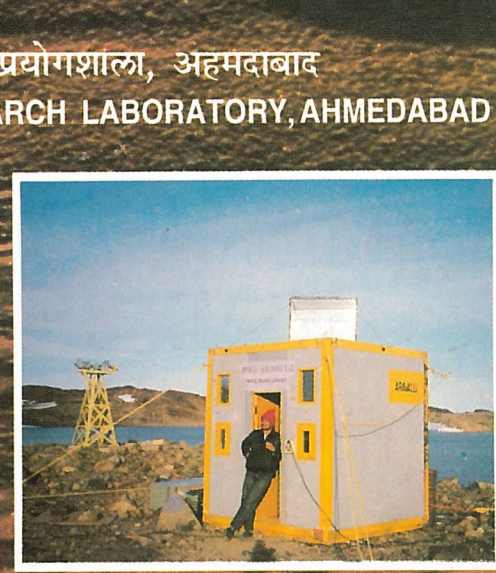

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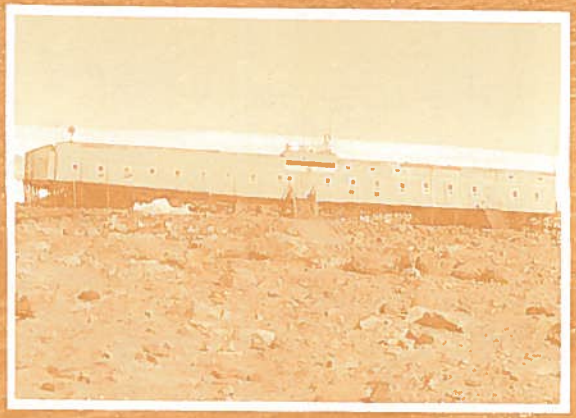

The permanent Indian Station at Antarctica - 'Maitri'.

The Optical Aeronomy Experimental hut at 'Maitri'.

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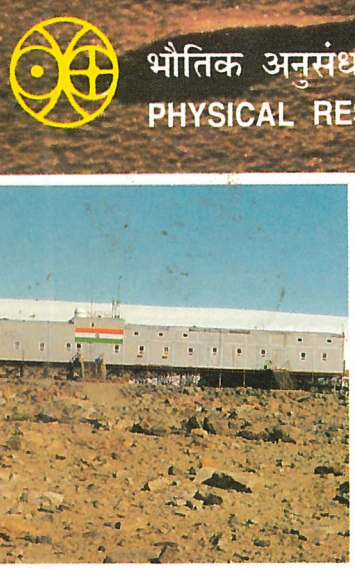

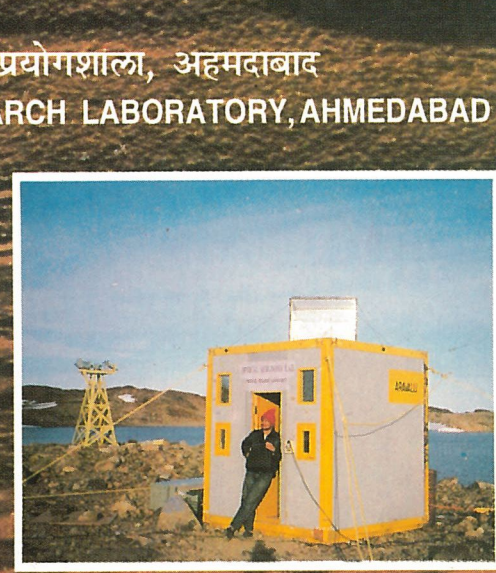

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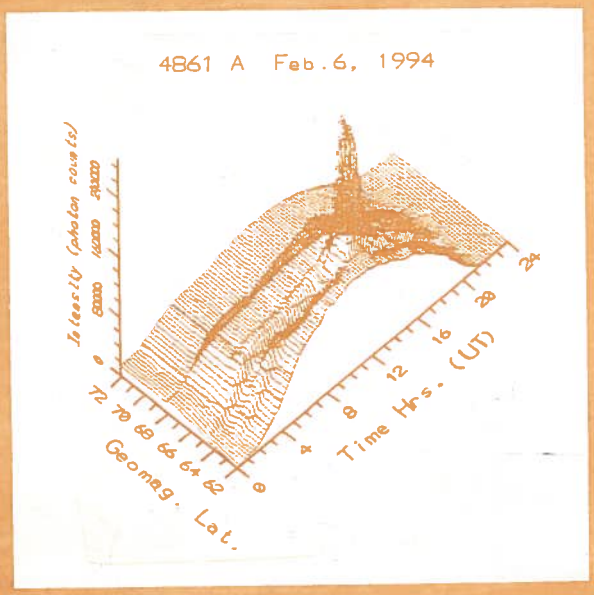
The top picture shows the new multiwavelength daytime photometer commissioned at Antarctica.

The bottom picture shows first results on 4861 A - H_β emission depicting the localised region of a energetic photon precipitation.



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Introduction

With the approach of the year 1995, we are close to the end of the current five-year plan period. This is, perhaps, an appropriate time to review the progress made on the scientific front as well as to look at the general *state of being* of the Laboratory. A detailed year-to-year review was already presented in the *Introduction* to the respective Annual Reports. I would like to present here a broad overview of the achievements made and the reorganisation effected over this period.

As the programmes of the Laboratory evolved with the passage of time and the leadership changed hands from the older to the younger generation of scientists, it became necessary to reorganize the areas of activities of the Laboratory into Divisions, somewhat different from the earlier ones. The two former different areas, namely *Infra-red Astronomy and Radio Astronomy* and *Interplanetary Scintillations,* are now merged into one *Astronomy and Astrophysics* Division. The whole of this division has moved to the Thaltej Campus which has now developed into a beautiful campus located in natural surroundings. Likewise, the two former areas known previously as *Geocosmophysics and Continental Palaeoclimate Studies,* and which were the components of the *Earth Sciences and Solar System Division* have recently been reorganized into the two new areas now called *Solar System and Geochronology* and *Oceanography and Climate Studies.* The other two divisions, namely the *Planetary Atmospheres and Aeronomy* and *Theoretical Physics* have remained unchanged.

A number of new programmes were initiated at the beginning of this period in the various divisions. These were of high international order. Indeed, some of them are very unique and have yielded unique scientific results, bringing high international recognitiion to the Laboratory and its scientists.

In the area of *Planetary Atmospheres and Aeronomy,* the emphasis has, over the years, been shifting from the studies of the upper atmosphere, in particular the ionosphere, to the studies of the middle atmosphere. To be sure, there are still continuing programmes, relating to the study of the ionosphere, such as the equatorial Spread-F. But there is now greater interest in the study of the thermosphere, an area which was not earlier addressed, mostly because these studies were much more difficult and the techniques for them have only recently been developed.

The main impetus for the study of the middle atmosphere has undoubtedly come from the concern caused by the anthropogenic changes in the atmosphere and one of the issues the International Geosphere Biosphere Programme (IGBP) generally addresses.

In view of the above mentioned emphasis, the programmes, initiated and carried out were (i) the development and employment of optical aeronomy techniques for the study of the neutral atmosphere, (ii) Lidar studies of the middle atmosphere to study the aerosol distribution in the stratosphere, (iii) the study of the atmospheric trace gases and chlorofluorocarbons in the middle atmosphere and (iv) laboratory studies of various photochemical reaction rates of astrophysical and aeronomic interest. Besides, interesting and comprehensive studies were also proposed and carried out, such as the investigation of the enigmatic equatorial Spread-F.

A number of highly sophisticated instruments and equipments were developed and acquired for carrying out these studies. Instruments like, Scanning Fabry Perot Spectrometers for line profile

measurements and All Sky Imaging high resolution spectrometers for mapping the dynamical parameters of the different airglow emitting regions were specially developed inhouse, making PRL one of the few places in the world having established such facilities. Co-ordinated ionospheric and thermospheric measurements revealed that the neutral atmosphere and the ionosphere exist as a closely coupled system. The imaging FPS provided the first visual representation of the reverse equatorial fountain. The most notable amongst the indigenously developed techniques is the *Dayglow Photometer*, the first of its kind. This has been used among others, to track the advance of equatorial ionization anomaly during daytime and also to evolve a method for obtaining a precursor to the equatorial Spread - F well before its actual occurrence. Further, the above technique has sucessfully been used in the detection and measurement of daytime auroral emissions from Antarctica. These are first time results because of the uniqueness of the dayglow photometer which was not available earlier anywhere.

Another instrument, the *All Sky Camera*, has been developed and used in conjunction with the day glow photometer, to study the equatorial Spread-F in a recently conducted highly successful campaign involving both the rocket-borne and ground-based observations. Non-linear simulation studies have been made to study the evolution of equatorial Spread-F. It has been conclusively shown that neutral dymamics plays an important role in the generation of irregularities.

For the study of the middle atmosphere trace gases and other anthropogenic pollutants, a cryosampler has recently been fabricated and flown. This development has enabled the middle atmospheric trace gas studies to become completely indigenous. Earlier results based on balloon-borne cryosampler studies provided the first profiles of Bromine related compounds which act as a source for Bromine radicals that are highly reactive and are extremely important in the ozone chemistry. Some of these compounds have been found to be increasing at an alarming rate (10 - 15% per year). Tropospheric near surface ozone, which is a very effective green house gas is extremely important for global warming. Systematic measurements of surface ozone and its precursors are being carried out from different locations in the country with a view to study the short and long term variabilities. Other interesting studies carried out over the years pertain to the nitrogen oxide compounds that are relevant to the ozone chemistry, as also measurement of positive and negative ion conductivities. The former has been included in the modelling studies to understand the diurnal variation.

For the study of the aerosol distribution, balloon-borne sun-tracking photometers have been developed indigenously. It has been shown for the first time that the land surface processes can influence tropical aerosol characteristics upto about 13 km and show a monsoon related biennial variation. At stratospheric altitudes, the aerosol characteristics were shown to be solely controlled by major volcanic eruptions with a residence time of the order of few years over the tropics. Further, a Nd-YAG Laser has been acquired and a Lidar developed which has already yielded interesting information on the structure and time evolution of the aerosol layers consequent upon the Pinatubo volcanic eruption of 1991. Pinatubo aerosol layer has also been studied by monitoring the twilight intensity at ground. Further, neutral air turbulence parameters in the mesosphere have been studied using both positive ion density and electron density probe flown on rockets.

For the laboratory astrophysics as well, an *Excimer Laser Pumped Tunable Dye Laser* has been acquired which will be used for the study of laser induced atomic and molecular reactions. The acquisition of this laser system has thus added new dimensions to the laboratory astrophysics studies and certain molecules of aeronomic interest have already been investigated.

In the *Earth Sciences and Solar System Division,* studies have been carried out, relating to Sun and solar system physics on the one hand, and the various palaeoclimatic and other earth surface processes on the other. These include, for the Sun and solar system physics, (i) characterisation of the solar nebula, the gas and the dust cloud from which the solar system objects are formed, (ii) identification of presolar and interstellar components in primitive solar system objects and the role that they played during the early evolution of the solar system, (iii) activity of the Sun during its early evolutionary phase, and (iv) late evolutionary history of the solar system objects, like moon, meteorites and the planets.

For carrying out some of these studies, a highly sophisticated mass spectrometer, known as the *Ion Probe*, had already been acquired in 1988-89 period and has been used since for the above studies. In particular, the most recent exciting result is the discovery of the (now extinct) ^{41}Ca (life time ~10^5 years) in pristine solar system grains in meteorities which has placed new constraints on time elapsed since the last injection of freshly synthesized elements in the solar nebula and formation of the first solid grains in the solar system.

In the studies on geochronology, an important contribution has been the dating of Deccan Trap Basalts, which has implications on the crust-mantle interactions at the time of eruption and also on delineating the cause for the K/T extinctions. High precision Ar-Ar dating in our laboratory has conclusively established that bulk of this eruption predates the K/T extinction by about 2Ma. In a related programme, different K/T boundary sites in India have been identified, the most recent one being the intertrappean sediments at Anjar. Studies of these deposits in India show that Deccan basalt eruption is not the cause for K/T boundary extinctions and that impact of K/T bolide did not trigger Deccan volcanism. A new development in the area has been the single grain Zircon dating using the Ion Probe based Pb - Pb isotope systematics. This technique should find extensive applications in studying the oldest rock formations in India.

In the other area of the Earth Sciences and Solar System Division, the focus of research is on the low temperature geochemical processes occurring on the Earth's surface and on the retrieval of palaeoclimatic and palaeoenvironmental information contained in various continental and marine repositories.

One of the important results of the group has been to assess the impact of the Himalayan Orogeny on the marine geochemical cycles of various elements and isotopes in the ocean. Detailed studies of the Ganga, Brahmaputra and the Indus rivers show that the Ganga/Brahmaputra have contributed significantly to the evolution of $^{87}Sr/^{86}Sr$ and U concentration in the ocean during the Cenozoic. If the high $^{87}Sr/^{86}Sr$ in these rivers result from weathering of silicates, it should have major implications in atmospheric CO_2 level in the past.

A major study on the application of ^{32}Si as an oceanographic water mixing tracer which began

earlier was brought to a fruitful conclusion during this period. The distribution of ^{32}Si in all the three major world oceans was measured and modelled to derive vertical advection and diffusion rates in the water column.

In palaeoclimate and palaeoenvironmental studies, our effort has been to determine their variations over different time scales and resolutions. These include high resolution ($\leq$ 1yr) short term ($\leq 10^3$ yr) repositories, such as tree rings, corals and glaciers and low resolution ($\sim 10^2$ - 10^3 yr) long term ($\sim 10^6$yr) recorders, such as deep sea and lake sediment peat deposits, deserts etc. These studies provide a means to look into the land-sea correlation of climatic records and also reconstruct palaeomonsoon conditions over the Indian sub-continent. Some of the important results obtained under this programme are (i) corals from the Lakshadweep and the Gulf of Kutch contain in them high resolution records of SST variations and air-sea exchange of CO_2, (ii) a variety of palaeoclimatic data from sediments of the Arabian Sea show that the Asian summer monsoon was weaker during the last glacial maximum than it is at present, (iii) the aeolian activity in the Thar desert began about 200 kyr ago, setting to rest the debate on its anthropogenic origin. The peak in aeolian activity post dates the glacial maximum at 18 kyr, a result at variance with the concept of synchronocity of continental aridity, aeolian dynamism and glacial epochs, (iv) the lake sediments in the Kashmir valley, the Karewas, provide a near complete record of geological and climate evolution in the region for the past ~ 4 Ma. Five cold (glacial) periods have been recognized in the section separated by temperate conditions.

The *Astronomy and Astrophysics Division* of the Laboratory has fabricated a wide range of back-end instruments including an imaging Fabry-Perot Spectrometer for seeing-limited velocity field mapping, optical and infrared (IR) photo-polarimeters, a CCD camera for wide-field imaging and an IR photometer with fast read out for lunar occultations of stellar sources. An IR CCD camera system called Near-Infrared Camera and Multi-Object Spectrograph (NICMOS) is being procured and a Fourier transform spectrometer for high spectral resolution and an FPS for medium resolution in IR are under development. The availability of such a wide variety of instrumentation makes PRL one of the very few places in the world having multi-faceted observational capability to tackle some specific astronomical problems.

The programmes undertaken for investigation which made use of some of these various instruments include (i) the studies of the planetary nebulae, their structure and dynamics, (ii) the studies of the active galactic nuclei (AGNs) such as the Seyferts, the Quasars, BL Lac objects, in photometry and polarimetry, (iii) lunar occultation in the IR and optical domain for high angular resolution studies, in particular, to determine accurate angular diameters of late-type stars and of dust shells around them, (iv) star formation processes and the structure and dynamics of HII regions around newly-born stars, and (v) the studies of topical events such as polarimetric and spectroscopic investigations of comets and velocity field structure of solar corona during total solar eclipses.

Notable among a number of interesting results obtained by the group during the last few years are: (i) a very short-time (~ 6 minutes) variability in flux and polarization in the BL Lac object OJ287;(ii) an evidence from IR photometry for early (< 10 days since the outburst) dust formation in the Nova Hercules 1991; and (iii) tracing of velocity field structure in the [OIII] line around the bar ionization front in the Orion Nebula, using the IFPS.

Regular observations using the 1.2 metre infrared telescope at Gurushikhar Observatory are likely to start from December 1994. After refiguring at Sinden Optical Co., the mirror is now at Gurushikhar and is being tested.

The Radio Astronomy and Interplanetary Scintillation area of the Astronomy and Astrophysics Division has been carrying out studies of the solar wind and the interplanetary medium. The three-station telescope located at Thaltej (Ahmedabad), Rajkot and Surat (initially) was designed to measure the off-ecliptic solar wind velocities. The Thaltej station has presently an area of 20,000 m^2 with Rajkot being 5000 m^2 while Surat which also had an area of 5000m^2 has been closed because of high level of radio noise at the frequency of operation of 103 MHz.

Interesting observations have been made from the Thaltej station on the scintillations of a radio source by the plasma tail of comet Halley and later of Comet Austin using another appropriate source. More recently, a rather spectacular burst event has been recorded from the pulsar PSR 0950+08, wherein the recorded average flux has been found to be about 60 times larger than the normal. Both of these are first observations of their kind.

The Udaipur Solar Observatory has also made substantial progress in obtaining high resolution pictures of solar flares and prominences. Some rather spectacular events have been identified and analysed for the physical processes underlying them. It has also now achieved the capabilities of obtaining, not only the narrow band images of the Sun in H-alpha line using Lithium Niobate Fabry-Perot-etalon Filter, but also to find the line of sight velocities of the solar prominences using a multi-slit Littrow Spectrograph. This is an important step for the study on the temporal and spatial structure of the motion and evolution of the solar prominences and their relationship with the magnetic field.

The *Theoretical Physics Division,* which started out initially with only the nuclear physics activity, has widened its scope dramatically over the years. The next activity, which was the first to be added was plasma physics. This was to provide a theoretical and experimental plasma physics environment in PRL whereby the space and ionospheric phenomena could be better understood and appreciated. The plasma physics group which expanded rapidly in the early seventies served the interest of the ionospheric physics very well indeed.

Further addition to the theoretical physics occurred in the form of atomic and molecular physics and gravitation. The basic motivation for these additions was to provide a thrust and support for the astronomy and astrophysics activity that had been initiated in the seventies. The Division was further expanded around 1988 and a new particle physics phenomenology group was added to include also cosmology as a part of astronomy astrophysics activity.

The activities of the nuclear physics group have continued to evolve with time. Over the last five years or so, the group has made important interesting contributions in the area of quark-gluon plasma where fascinating plasma modes of oscillations have been found arising out of the non-abelian nature of the system. Another important contribution is the determination of nucleon-nucleon interaction phase shifts using the fundamental quark degrees of freedom. This dispenses the need to involve pions to mediate the interaction.

The high energy group, which is the strongest phenomenology group in the country today has been making important contributions with respect to neutrino masses and neutrino oscillations which all have astrophysical and cosmological significance.

The highlight of the contributions in the atomic physics area is the development of the boundary corrected theory as a proper formulation of the charge transfer problem.

A small group of scientists have also been devoting to the problems of classical and quantum chaos, integrability in classical mechanics and the question of classical-quantum relationship. Interesting results have been obtained for a quantum quartic oscillator showing fascinating eigen-function sequences. In the area of classical-quantum relationship, existence of non-Planckian discrete allowed and forbidden states have been predicted and also observed.

The activities of the small plasma physics group of PRL have over the years concentrated mostly on research relating to space and astrophysical plasmas as, for example, the structure and dynamics of the magnetospheres of compact objects and associated accretion discs and a self-consistent dynamical theory of global galactic magnetic fields. The group has also carried out significant investigations in dusty plasmas, a field in which it has recently embarked upon.

A monsoon dynamics group, which was started during the seventies, carried out important work in the area of monsoon variability on the intra-seasonal time scale, in particular, on the physical mechanism of the 30-50 day oscillation and its northward propagation. It is now engaged in carrying out modelling involving the effect of heat source asymmetry arising from the Tibetan plateau and associated effects.

The overview given above has also covered some of the important contributions made during the current year. The main highlights and the details of these contributions are presented in the subsequent chapters.

A glance at the overview, as presented above, of the contributions made over the last five years or so shows that PRL scientists have made a large number of outstanding scientific achievements over a wide spectrum of disciplines. These undoubtedly are a result of sustained hard and painstaking work, carried out many a time under trying conditions. Science is universal and more so pure science. Any kind of handicap cannot be given as an excuse for anything less than the best of science in this highly competitive international venture. That, in spite of the many manifest comparative handicaps, our scientists have been able to record world class achievements, goes entirely to their credit. Indeed, some of the achievements are first ever and others are first rate and have thus brought great international honour and recognition to the Physical Research Laboratory and to themselves.

I take this opportunity to extend my heartiest congratulations to the faculty for these achievements. However, these achievements place all the greater burden of responsibility on the faculty to do even better in future. One cannot afford to be complacent. There lie ever greater challenges to meet in order to be constantly on the cutting edge of frontiers and creativity.

While we should clearly recognize the extent of our achievements, we ought to be at the same time aware of the areas that need further improvement. One such area, as I have repeatedly men-

tioned, is one of modelling of the various phenomena which are the subject of experimental studies at PRL. The value of the modelling work can hardly be overemphasized. Theoretical models of phenomena provide frameworks in terms of which the experimental results can be better understood and appreciated and their full value can be realized. They can also provide a guide for one to determine which experimental values and data points need to be further obtained experimentally. It is hoped that the modelling activity would continue to be strengthened in future.

As research investigations have covered greater and greater grounds in almost all disciplines, they have tended to become more and more complex, and have thereby required greater coordination among scientists in a particular area. Complementation of expertise to carry out a particualr complex project has become more of a necessity in this highly competitive international venture, in order to be able to register a greater impact of the work done. Furthermore, the choice of the problems to be undertaken for investigation is another crucial point which determines the impact factor of the work done.

Considering these points, it was, therefore, thought desirable to introduce a different mode of carrying out research activity whereby groups of scientists propose research projects to be carried out which require their complementary expertise and which cover areas of research having a potential impact factor. This mode should, by the very nature of things, help bring scientists closer together encouraging them to work towards the project in a missionary zeal. This mode has been in operation over the last couple of years, and it is hoped that this will yield desired results in time to come. Some positive results are already in evidence.

It may, perhaps, be also appropriate to record other developments that have occurred in PRL over the last five years or so, relating to some general and technical facilities and amenities.

Very recently PRL has acquired a high speed IBM computer RS 6000 consisiting of two 580 Compute Servers, two 580 Time Sharing Servers, and one 580 File Server having a speed of 39 Mflops each, complete with high speed graphics and a range of software packages. These have already been networked with other work-stations and PC's and thus constitute quite a powerful and versatile computing environment for PRL.

With an institution with as diverse a set of disciplines as there are in PRL, the library space requried to accommodate the ever increasing number of books and journals keeps constantly wanting. The library was, therefore, further expanded to include also the ground floor which earlier housed the canteen. The library space requirement is hopefully now taken care of for the next ten years.

For a long time, a need had been felt for PRL to have its own auditorium, which grew stronger as more and more conferences were organised at PRL, both national and international. An auditorium with a capaicty of 310 was thus constructed and later named as K. R. Ramnathan Auditorium as a tribute to Dr. Ramnathan's contributions to PRL as its first Director as well as for his continued association with PRL until his death.

The physical environment of a work place is a very important element in the overall state of being of an institution as also an indirect effect that it has on its social environment. The overall apprearance of PRL has over the years undergone a sea change and the physical environment is

undoubtedly much pleasant today. This has required sustained efforts on the part of the concerned members of the staff and faculty. I would like to commend members of the staff and faculty for their efforts whole-heartedly and would like to hope that these efforts would continue.

However, as important as the physical environment, is the social environment and the interpersonal relationship among the members of the staff and the faculty. It must be said that the interpersonal relationship at PRL is quite cordial, with members of the staff taking active part in the various social and other functions that have been organised from time to time.

A particular occasion, which gives me great pleasure to recall is the Open-House Exhibition that was organised in March 1989. It was an occasion when the whole of PRL was involved as a family in presenting a most spectacular show with a spirit of great dedication and enthusiasm. Such a spirit, I am sure, will continue to be exhibited by the staff members of PRL.

The *Introduction* to this year's Annual Report would be my last as the Director of PRL. I will like to take this opportunity to record my thanks to all my colleagues of PRL for the tremendous spirit of cooperation and dedication that they have exhibited in doing all that I have outlined above and much more. Whatever development has happened at PRL is due to their efforts, one and all. I should be happy if I have helped in this in a small way.

DIRECTOR

ASTRONOMY AND ASTROPHYSICS

The academic activities of the astronomy and astrophysics division are, in essence, multi-faceted and encompass several windows of the electromagnetic spectrum, utilising a variety of instrumentation, a majority of which has been built in-house. The wide range of scientific programmes that the division has been pursuing include the problem of understanding the solar flares in relationship with magnetic fields, the investigations pertaining to the star formation and the stellar evolution and the studies to solve the enigma of the central energetic source in the active galactic nuclei. The Udaipur Solar Observatory at Udaipur for regular solar observations, the Gurushikhar Observatory for optical and infrared astronomy at Mt. Abu, and the transit radio telescopes at the field stations in Thaltej and Rajkot for the Interplanetary Scintillation form the principal centres of activity of the division.

The Udaipur Solar Observatory(USO) has now achieved the capabilities of obtaining not only the narrow band images of the Sun in H alpha line using a Lithium-Niobate Fabry-Perot etalon filter, but also , to find the line-of-sight velocities of the solar prominences using a multi-slit Littrow Spectrograph. The emphasis of the work has been on the temporal and spatial structure of the motion and evolution of the solar prominences and their relationship with the magnetic field.

Following the detection of an intense radio burst from the Pulsar PSR 0950+08, attempts are now being made to understand the energetics of the event and its possible causative mechanism. An interesting scenario to explain the observed radio burst and the subsequent enhancement in the D region ionospheric absorption is that of a fragmented comet crashing on the pulsar. The radio astronomy group is also trying to open up new possibilities of detecting flares from late-type stars, using the IPS transit radio telescopes at Thaltej and Rajkot. Furthermore, there have been efforts to investigate the processes underlying the solar plasma acceleration using the solar wind data obtained from the IPS observations.

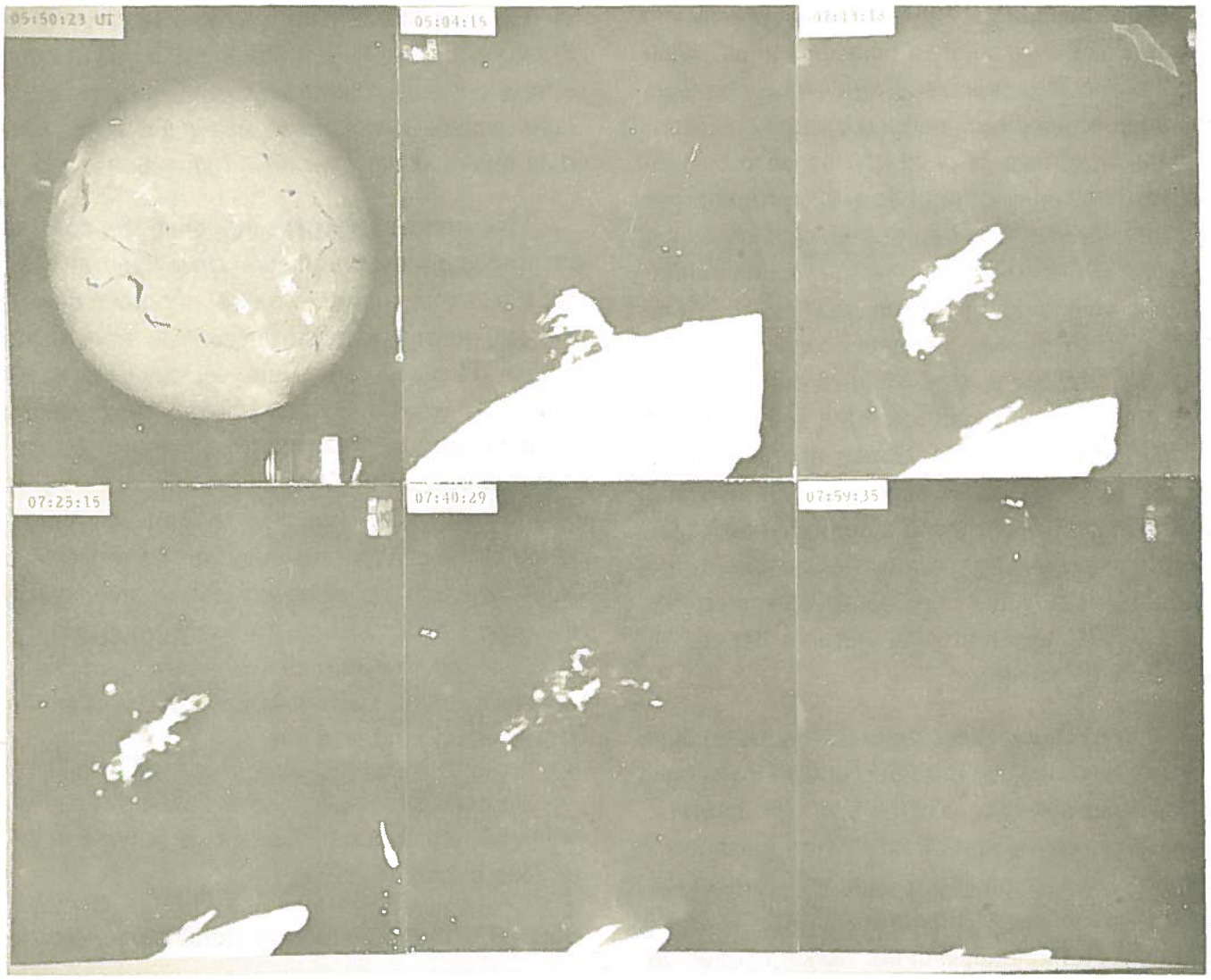
With more exciting results coming up from the sophisticated instrumentation developed at PRL, like the Imaging Fabry-Perot Spectrometer detecting jets from young stellar objects and jumps across ionization fronts in the velocity fields of HII regions, the infrared fast photometer revealing asymmetric structure of late-type giants from lunar occultation observations, and the photopolarimeter providing significant clues to unravel the mysteries of the central engine in the Active Galactic Nuclei through the discovery of micro-variability, the optical and infrared astronomy group is gearing up to the challenge of making the best use of the facility of the 1.2 m telescope at Gurushikhar, Mt. Abu soon to be available.

In what follows, is given a detailed report on some of the important scientific work done in the division during 1993-94.

SOLAR PHYSICS (Udaipur Solar Observatory)

2-D Velocity Studies of an Eruptive Prominence of 14 January 1993

A large number of erupting solar prominences have been observed from USO using both 26-cm aperture high resolution spar telescope and the 15-cm full disk solar activity patrol telescope. The processes of formation, stability and eruption of the prominences are not well understood. It is important to study the velocity and magnetic field structures at various stages of its evolution in order to understand the prominence phenomenon. A spectacular erupting prominence was observed in H-alpha on January 14, 1993 from USO. The sky-



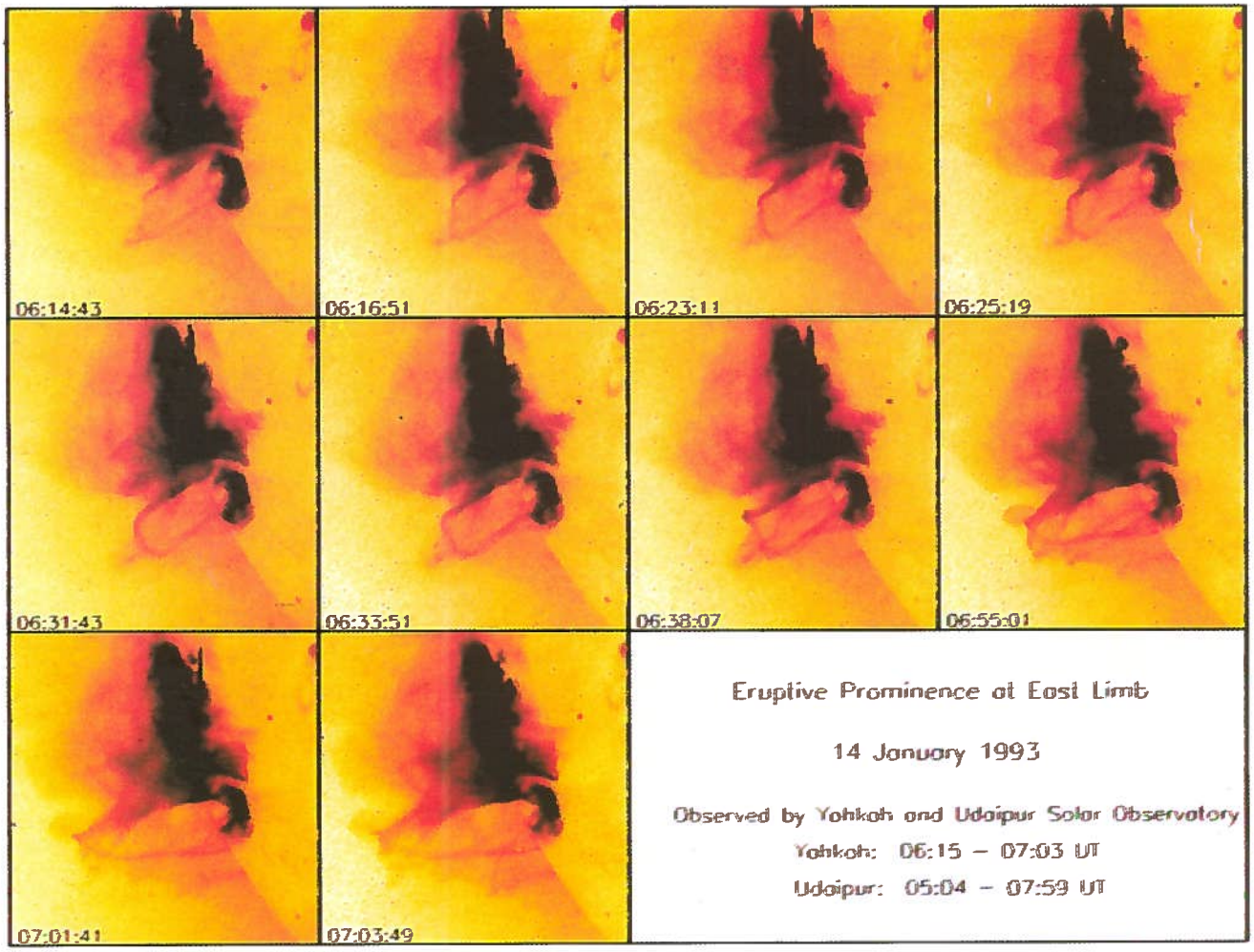
1.1 The eruptive prominence as observed from USO in H-alpha on January 14, 1993 during 05:04-08:00 UT. The first frame is a full disk picture taken at 05:50:23 UT showing its location on the solar limb.

plane velocities were measured corresponding to several knots or fragments of the prominence (Fig. 1.1). It was found that the erupting knots followed helical trajectories. It was also observed that their velocities did not increase/decrease monotonically. On the contrary, the knots experienced sudden accelerations in their motions at various heights. Corresponding to this event, soft X-ray data obtained by the Japanese satellite YOHKOH were also studied under an Indo-Japanese collaborative programme. The soft X-ray images were obtained just before the eruption observed in H-alpha, displaying a very interesting non-potential magnetic field configuration associated with the event (Fig. 1.2).

(A. Bhatnagar and S.C. Tripathy)

3-D Velocity Solar Observations

From the usual H-alpha image observations, it is possible to determine only the sky-plane velocities associated with dynamic events, such



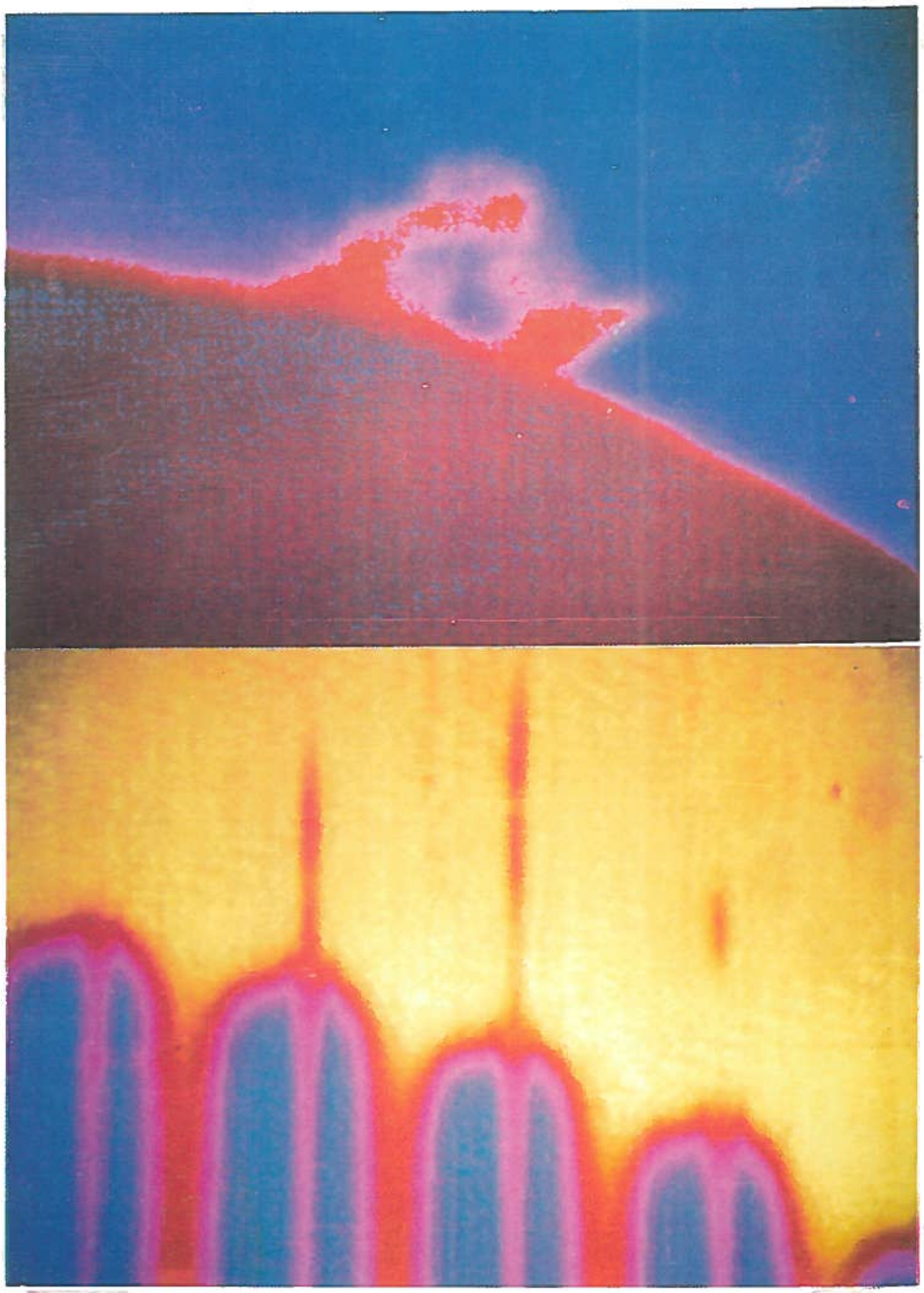
1.2 Eruptive Prominence of East Limb, 14 January 1993 observed by Yohkoh and Udaipur Solar Observatory. Yokoh : 06:15 - 07:03 UT ; Udaipur : 05:0 - 07:59 UT

as, solar flares, surges, sprays, and prominence eruptions. However, with the development at USO of a multi-slit Littrow Spectrograph, it has now become possible to obtain line-of-sight component of velocity field. A 6" aperture Carl Zeiss Coude telescope feeds the sunlight to the spectrograph. The spectrograph has a dispersion of 6 A per mm, and a spectral resolution of 0.13 A. The image size is 6 cm, and area covered on the CCD detector is around 3 x 4 arc-min^2. Arrangement is also made to simultaneously record solar images along with the superposed slit-positions. From the Doppler shifts of H-alpha line at various slit-positions, one is able to derive line-of-sight motion at various locations, in the range 5-450 km/s. Fig. 1.3 shows a quiescent prominence observed on June 7, 1993, and the corresponding spectra recorded through the spectrograph.

(Nandita Srivastava and Shibu Mathews)

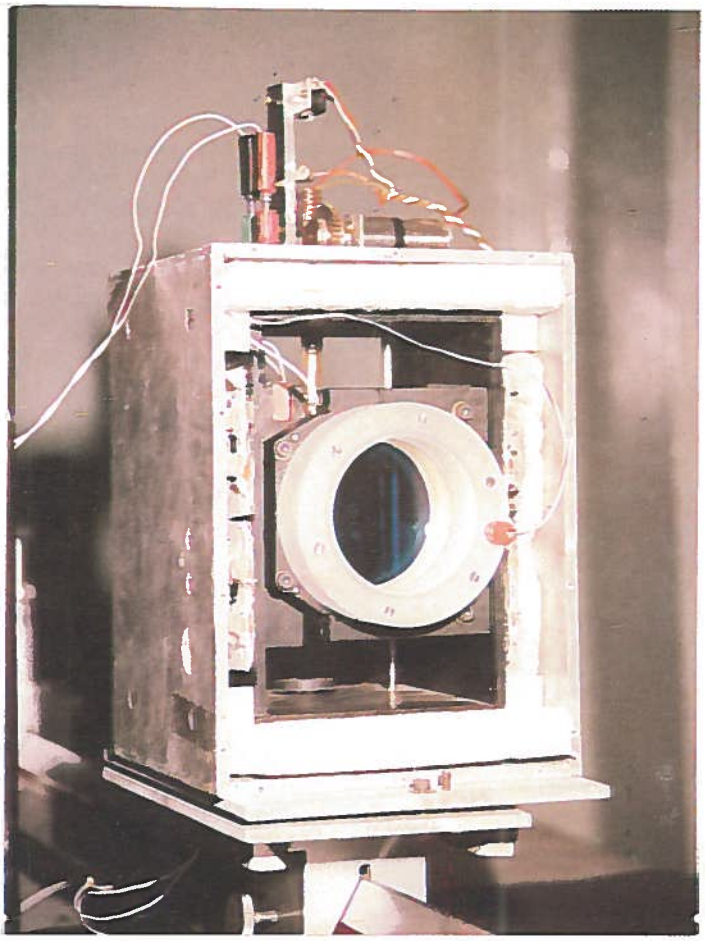
Solar Observations Using a Lithium Niobate Fabry-Perot Etalon

Solar chromospheric observations at USO are usually made using narrow passband (0.5A/



1.3 A quiescent prominence observed at the location S10W90 on June 7, 1993 in H-alpha line (top). Corresponding spectra of the prominence recorded through an H-alpha multislit spectrograph at Udaipur Solar Observatory is shown at the bottom. The spectra refer ot three different slit positions on the prominence. The Doppler shifts of these H-alpha lines have been measured in order to determine the line-of-sight velocities in the prominence.

0.7 A) Halle birefringent filters tuned at 6563 A H-alpha line. These filters are very expensive, and are not readily available. Moreover, these filters are limited by their lower throughput, smaller usable aperture, and higher temperature sensitivity. To examine the possibility of replacing the old and deteriorating Halle filters at USO, a comparatively inexpensive 60 mm aperture Lithium Niobate



1.4 $LiNbO_3$ Fabry-Perot etalon enclosed in the temperature controlled chamber.

1.5 H-alpha Filtergram with $LiNbO_3$ Fabry-Perot etalon filter on July 4, 1993.

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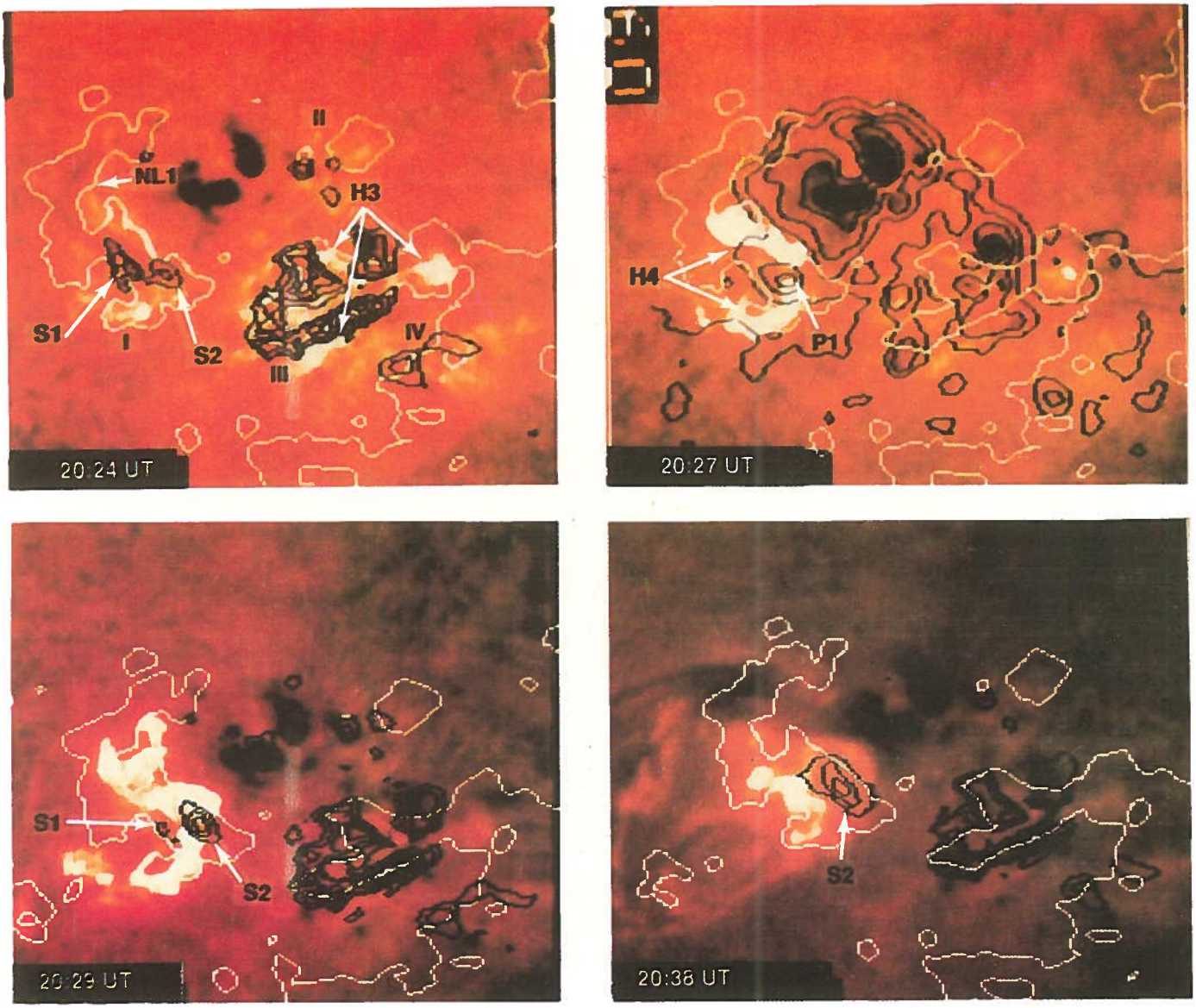

II
NL1
H3
S1
I
S2
III
IV
20:24 UT
H4
P1
20:27 UT
S1
S2
20:29 UT
S2
20:38 UT

Fabry-Perot (FP) etalon has been acquired from CSIRO, Australia. These FP etalons are made by cutting a wafer parallel to Z or Y axis of Lithium Niobate crystal, two surfaces of which are polished and coated with dielectric material. The refractive index of the crystal can be varied by applying voltage, thereby providing wavelength tunability. This etalon is being tested to be used as a narrow passband filter for taking video magnetic and velocity field observations in 6122 A line of CaI, and chromospheric observations in H-alpha line. The free spectral range and finesse of this etalon at 6122 A are 4.6 A, and 29 respectively, giving a bandpass of 150 mA. The filter can be tuned with a sensitivity of 5.7×10^{-4} A/volt. The large throughput and wavelength tunability of the Lithium Niobate etalon are added advantage; however, the small field of view imposes some limitations. We have carried out bench tests, and obtained preliminary observations in H-alpha 6563 A and CaI 6122 A. Figs. 1.4 and 1.5 show the etalon enclosed in a temperature-controlled chamber, and a filtergram taken by using the etalon.

(C. Debiprasad, Shibu Mathews, A. Bhatnagar and A. Ambastha)

H-alpha Intensity Oscillations Observed in Extended Flares

It is known that the solar chromosphere oscillates with a period of 120-300 seconds. With the aim of detecting the chromospheric intensity oscillations, we have analyzed H-alpha images before, during and after a large extended 2B flare of 20 April 1991. Filtergrams were taken at a rate of 1-20 frames per minute during the period of the flare. In all, we digitized 300 selected H-alpha filtergrams using IDAS Data Acquisition and Analysis System at USO. The frames were registered pixel by pixel using IRAF to remove guiding errors. Various corrections were applied to reduce non-solar effects. Any contrast variation from frame to frame due to seeing variation was removed by subtracting the rms intensity of chromosphere (I_{ch}) of each frame from the intensity of each flare kernel on the same frame. The flare kernel intensities (I) were further normalized with respect to the quiet time frame intensity taken 10 minutes before the onset of the flare. Time-profiles of relative intensity variations $(I-I_{ch})/I_{ch}$ were obtained at several locations over the flaring site. The power spectra of the intensity profiles indicated predominant 3 and 5 minute oscillation modes in the flaring area as well as in quiet chromosphere. However, it was found that the power in these modes was larger in flaring area as compared to the quiet areas. In order to verify these preliminary results, further work is in progress.

(Rajmal Jain and S.C. Tripathy)

Evolution and Flare-Associated Magnetic Shear Variation in Solar Active Regions

Flare activity of solar active regions is generally believed to depend on stressed or non-potential configuration of magnetic fields. As an active region evolves, stresses in the coronal magnetic field may build up in response to changes taking place at photospheric level, such as sunspot motions, and emerging fluxes. Free energy of these stressed, non-potential fields is considered to be available for release in flares. However, several cases have been reported where strong shear existed in certain areas, and yet no major flares occurred. There are also cases when major flares occurred in areas with almost no shear. It is therefore desirable to determine how various magnetic parameters evolve during an active region's development, and particularly during the time of flares. We have studied the evolution of

non-potential magnetic fields in NOAA AR 6555 during March 23-26, 1991, using a quantitative description of shear. It is found that flare-active areas evolved more significantly in the overall structure. Flare ribbons mostly preferred to form in areas bordering, and *not within* the areas of strong shear.

Using overlays of H-alpha filtergrams, and NASA/MSFC Vector Magnetograms, we found that statistically significant change in magnetic shear occurred in spatial and temporal proximity of several flares. Fig. 1.6 shows change in magnetic shear during a large 4B/X4.7 flare observed on 26 March 1991 in AR 6555. A particularly interesting feature, detected for the first time, is a sudden decrease in the area-averaged shear index around the flare onset time, in some flare events. In an attempt to determine the state of shear at flare onset time, and to establish the essential nature of associated shear changes, we have analyzed several flares of different types, which occurred in active regions with widely varying magnetic complexities. This work was done in collaboration with Mona J.Hagyard and E.A.West of MSFC, USA.

(A. Ambastha)

A Study of Photospheric Magnetic Fields Associated with the June 1991 Active Region

Active region NOAA AR 6659, on the Sun in June 1991, was characterized by extensive flare activity. These flares ranged from small C-class events to the five gigantic X10-12 flares that erupted at intervals during the region's disk passage. While much of the flare activity occurred at different locations in the region, the five X-class events were all localized along one section of the region's magnetic neutral line. We have examined vector magnetograms obtained from NASA Marshall Space Flight Center's Solar Observatory to determine why this particular area was associated with such energetic events. We also analyzed sequences of vector magnetograms taken before, during and after several small flares, and show that, in the case of one particular subflare, the weighted shear index (area-averaged angular shear weighted by the mean transverse field strength) changes at the time of this event. This work was done in collaboration with M.J.Hagyard, E.A.West, J.E. Smith and E.G.Kenny of MSFC, USA.

(A. Ambastha)

The Magnetic Evolution of AR 6555 which led to Two Impulsive, Relatively Compact X-Class Flares

We have studied the evolution of the vector magnetic field and the apparent sunspot proper motions in AR 6555 during a four day period of March 23-26, 1991. This region displayed two areas of large flare activity- one of them experienced a large flare before our observation period, and the other displayed two large flares of X-class. These two X-class flares had very similar light-curves, energies, and other characteristics, although the active region appeared to have changed substantially in the period between them. These flares occurred near locations of large magnetic shear, but not where the shear was strongest. Potential field extrapolations of the observed field suggest that the changes in overall field topology were such that a null of the coarse magnetic potential field appeared near the time of the first of the two flares at a location close to that of both flares. This null, then, remained in that location for a few days while the two X-class flares were observed. The flares occurred around an included polarity region where a particular pattern of the

vector field and sunspot motions indicated a "squeezing" of material along the polarity inversion line. This pattern was very different from that usually associated to the shearing of arcades. The observed electric currents, inferred from the transverse magnetic field, were consistent with this pattern. Other characteristics observed near the time when the region experienced its first flaring are the major reconfiguration of the longitudinal field and the vertical electric currents. Both changes imply substantial variations of the magnetic structure of the region. On the basis of all the available data we suggest a scenario that can explain the origin of the magnetic free-energy that was released in these flares. This work was done in collaboration with J.M. Fontenla, B. Kalman and Gy. Csepura of MSFC, USA.

(A. Ambastha)

Study of Solar Structure Based on Opacity Modifications

The internal structure of the Sun is estimated from the computation of Standard Solar Model through the theory of stellar evolution. The numerical techniques used for computing these models depend on the assumed input physics describing the properties in the solar interior. The result of such calculations is tested by comparing the calculated frequencies of solar oscillations with those of the observed ones. Although the theoretical frequencies match with the observed ones accurately, discrepancies do exist and these discrepancies are significant to understand the internal properties of the Sun.

To study the effect of the opacity on the structure of a solar model, we have computed static as well as proper evolutionary models of the present Sun where the opacity as a function of temperature is artificially modified. These models were calibrated to have the solar radius and luminosity at the assumed age of 4.6 billion years by adjusting the parameters of the model. The calculations illustrate that the structure of the Sun is independent of the opacity changes beyond the base of the convection zone except the region very near to the surface. Further, we demonstrate that the changes in the model in the convection zone can be well understood in terms of the simple envelope models with the same input physics. This work was done in collaboration with J. Christensen-Dalsgaard.

(S.C. Tripathy)

Properties of Cometary Plasma and Enhanced Radio Source Scintillation

Following the 1985 apparition of Comet Halley, there have been a number of attempts for estimating the electron density fluctuation in the cometary plasma, using the IPS technique. Basically the method involves measuring the enhanced radio source scintillation index, while the source is occulted by cometary plasma. It is believed that the enhanced scintillation of radio sources may be detected when the occulting geometry is favourable. We suggest that the electron density fluctuation in the cometary plasma tail derived from the radio source scintillation measurements by assuming the typical values of tail plasma density and velocity is an over-simplification. We have used enhanced scintillation in the direction of quasar 3C411 while occulted by Comet Austin, along with the plasma density values derived from the optical observations, and realistic values for velocity. By comparing with the previous results, we found that the ion density modulation is only around 40%.

(C. Debiprasad)

RADIO ASTRONOMY & INTERPLANETARY SCINTILLATION

Angular Source Size Measurements and Interstellar Scattering at 103 MHz

Data obtained between 1984 and 1987, using the Thaltej radio telescope with a 10,000 m^2 dipole array operating at 103 MHz, was used to determine the angular diameters of fourteen strongly scintillating radio sources. The method used exploited the technique of Interplanetary Scintillation (IPS), wherein the systematic variation of scintillation index (m) with solar elongation (ε) was used as a unique indicator of the source size. The method has been used before, but these are the first measurements at 103 MHz. These values were then used in conjunction with similar available measurements at 151.5 MHz to determine the contribution of interstellar scattering (ISS) to source broadening at 103 MHz. The results confirmed enhanced scattering in the plane of the galaxy due to ISS.

(P. Janardhan and S.K. Alurkar)

A 327 MHz IPS Survey of Radio Sources Over 6 Steradian

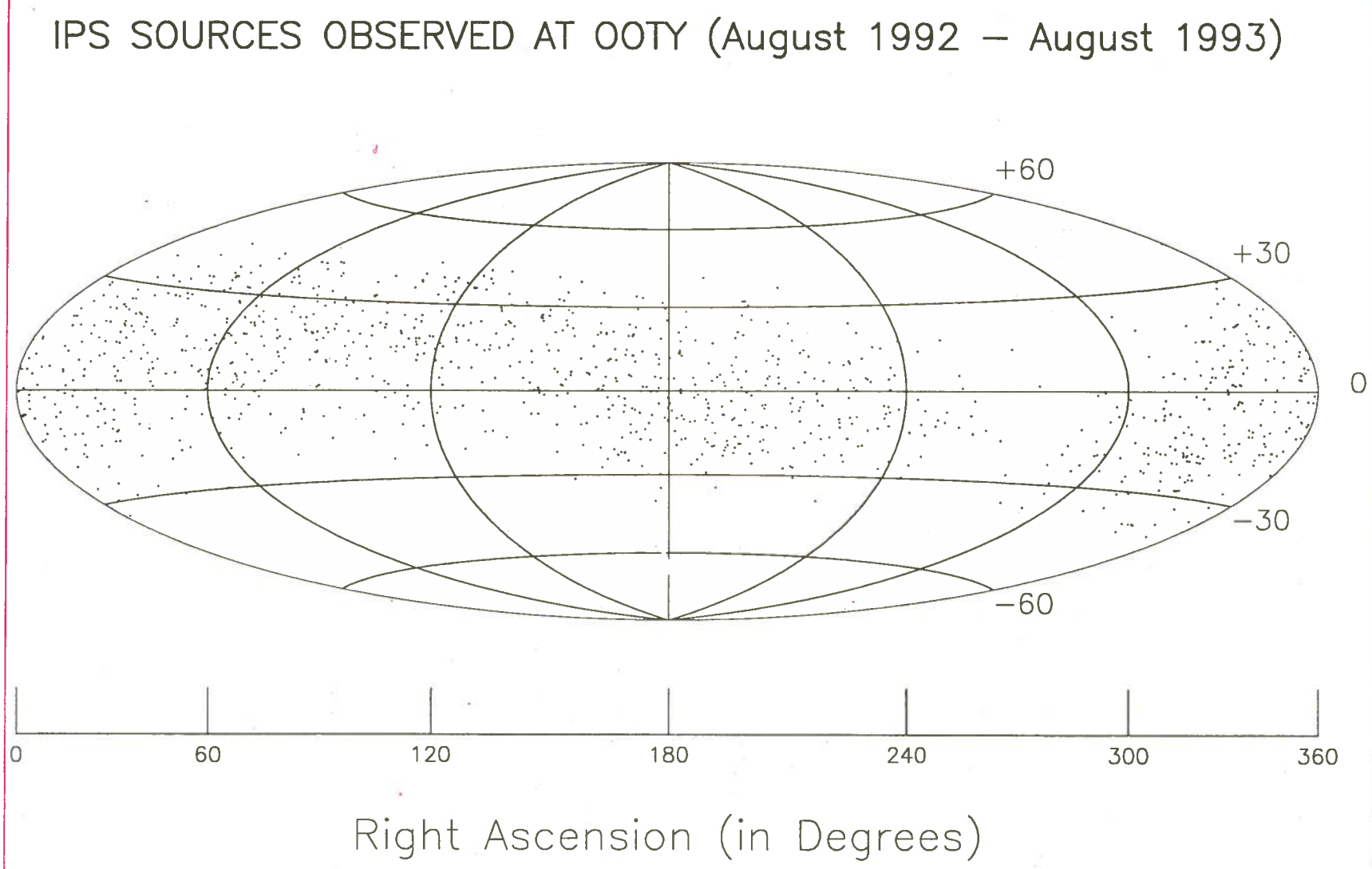
The first phase of the interplanetary scintillation (IPS) survey (which was begun in August 1992) using the Ooty Radio Telescope (ORT), to detect compact sources was completed by September 1993. Preliminary analysis of this data has resulted in a list of approximately 1000 sources having angular size less than 500 milli arc seconds. During the course of the survey, several cases of enhanced IPS, caused by travelling interplanetary disturbances which crossed the line-of-sight to the compact radio sources were detected. The final list of compact sources which are distributed widely in space, is shown in figure 1.7 and can be used to undertake systematic studies on interplanetary weather prediction. This work was done in collaboration with S.Ananthakrishnan, Balasubramanian and Manoharan of TIFR Radio Astronomy Centre at Ooty.

(P. Janardhan)

Further Studies on the Pulsar PSR 0950+08

Several studies were carried out on the pulsar PSR 0950 + 08, following the unique observation of a radio scintillation burst on 29 July, 1992. The most important of these are the following:

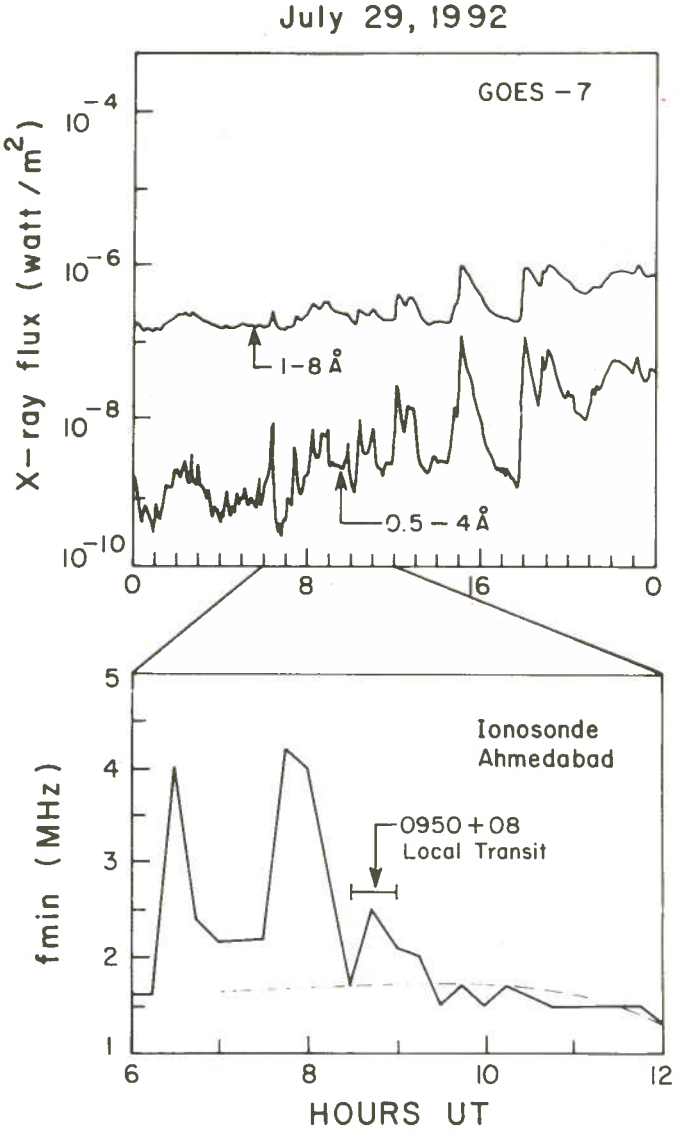
Comparison of the X-ray emission from PSR 0950+08 with the large solar flares: The pulsar 0950+08 is not a known X-ray emitter, but on July 29, 1992, there seems to be a convincing, though indirect evidence that the pulsar not only emitted X-rays during the active phase, but its magnitude was comparable to very large solar X-ray flare. This evidence comes from the ionospheric sounding (Ionosonde) observations. The minimum frequency (usually termed as 'f_{min}') at which echoes are observed in the Ionosonde depends among other terms on absorption present in the ionosphere and thus can be used as an absorption index. An excess ionization in the 'D' region of the ionosphere produced by an extra flux of X-rays due either to flares from the Sun or any other cosmic source leads to absorption of radio waves and hence an increase in f_{min}.



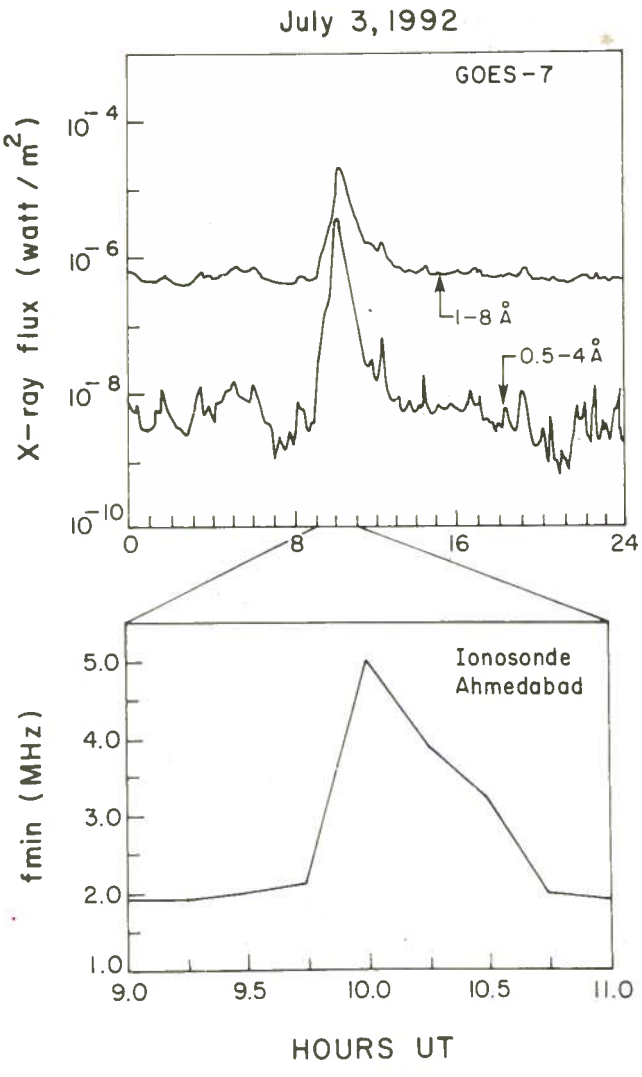
1.7 IPS sources observed at 327 MHz.

On July 29, 1992, when the pulsar was observed, the 'f_{min}' was found to be 1.7 MHz at about 0600 UT, later it increased and showed three distinct peaks at 4 MHz, 4.25 MHz and 2.8 MHz (Fig. 1.8). Finally, at 0915 UT and thereafter 'f_{min}' behaved normally.

For comparison with this event we picked four major solar X-ray flares in the period of about a month preceding the event. Solar X-ray measurements in the range of 1-8 A and 0.5-4 A by GOES-7 satellite indicated X-ray flares on June 28, July 3, 7 and 8 1992. The temporal variation in 'f_{min}' observed at Ahmedabad during the period of each flare clearly indicated that large solar X-ray flares increase the 'f_{min}' (Fig. 1.9). The remarkable point was that on July 29, 1992 the Sun was extremely quiet and GOES-7 measurements of solar X-ray in the range of 1-9 A and 0.5-4 A indicate very low level of emissions in these bands, but the increases in 'f_{min}' were large. These increases compare with those of the four major solar flares discussed



1.8 Figure shows three peaks in 'f_{min}' as indirect evidence for X-ray emission from PSR 0950+08 on July 29, 1992.



1.9 Figure shows the 'f_{min}' increase due to a large solar X-ray flare on July 3, 1992.

above. Thus we believe that, although PSR 0950+08 is not a regular X-ray source, during its active phase on July 29, 1992, the pulsar emitted large X-ray energy which produced excess ionization in the D-region of the ionosphere. This excess ionization increased the 'f_{min}' as observed by Ionosonde. This comparison indicates that the X-ray flux from PSR 0950+08 during the active phase should be comparable with the major solar flares i.e., in the range 10^{-5} to 10^{-4} W/m^2.

(M.R. Deshpande, H.O. Vats, H. Chandra, P. Janardhan, A.D. Bobra, G.D. Vyas, C.R. Shah, K.J. Shah, S.L. Kayasth, and Bharati Bhatt).

Energetics of the event: On the assumption that the absorption of HF radio waves as indicated by 'f_{min}' observations is due to X-ray emission from the pulsar, the expected X-ray flux during the three peaks of 'f_{min}' should be in the range of 10^{-5} to 10^{-4} W/m^2. However, for the third peak it could be slightly lower than 10^{-5} W/m^2. It is interesting to note that the first two peaks seem to be an order of magnitude larger than the third one (in terms of X- ray emission). The radio telescopes used for recording direct radio emissions from the pulsar were able to do so only during the third peak (as these telescopes are transit instruments). Instead, if the radio observations were made during the first two 'f_{min}' peaks, the observed radio intensity would be much larger than the present observations (the increase possibly could be by an order of magnitude). The X-ray flux of 10^{-5} W/m^2 gives a luminosity of 2.6 x 10^{37} ergs/sec (for this the duty cycle of the pulsar is taken as 12 msec and its distance 0.1 kpc). The X-ray luminosity during the active phase is close to the critical luminosity and will require accretion rate to be 2.8 x 10^{14} Kg/sec. If we assume that the excessive accretion during the event lasted for a period in the range of 30 minutes to about an hour then the total excess mass accreted during the event would be in the range of 5 x 10^{17} Kg to 10^{18} Kg. This mass is nearly equal to that of a large comet-like object. Thus it may be conjectured that the observed effects are due to an accretion of comet-like object by the pulsar. The comet perhaps fragmented into three parts in the vicinity of the pulsar. The material would ionize before it impinges into the accretion cone of the pulsar and could have produced three peaks in 'f_{min}'.

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

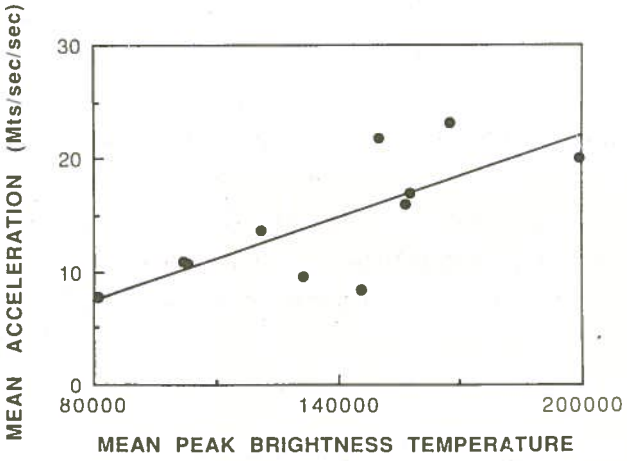
Radio Observations of Flare Stars

There are several stars known to be flaring. These are mostly M type stars. During the course of our IPS observations we recorded radio flares from π Leo. There were two flare events on (1) September 29, 1993 and (2) September 30, 1993. These were recorded simultaneously by both our radio telescopes at Thaltej and Rajkot. The first event was very strong about 5-6 times larger than the other one. The preliminary calculation indicates that the energy released from the star (π Leo) during this flare seems to be 10^8 times more than a strong flare from the Sun. Further analysis of this and a few more events is going on.

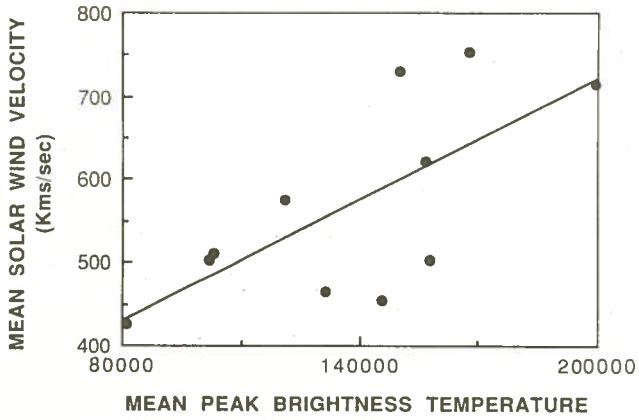
(M.R. Deshpande, H.O. Vats, C.R. Shah and S.L. Kayasth).

Radio Brightness Temperature and Solar wind Acceleration

The question of solar wind acceleration is most fundamental and even today a definitive answer to this question is not in sight. However, it is important in astrophysics for its role in mass and angular momentum transfer in the stellar environment. We made an attempt to compare the radio brightness temperature with estimated



1.10 Figure shows the dependence of mean solar wind acceleration on mean peak brightness temperature.



1.11 Figure shows the dependence of mean solar wind velocity on mean peak brightness temperature.

acceleration of solar wind. The estimation of acceleration is done using a simple model for the dynamics of plasma and the observed solar wind velocity in the interplanetary medium by IPS method. The radio brightness temperature (T) seems to have the following relation with solar wind acceleration (A) and velocity (V) (Figs. 1.10 and 1.11) :

$$A = -2.1 + 1.2 \times 10^{-4} T \quad \ldots (1)$$

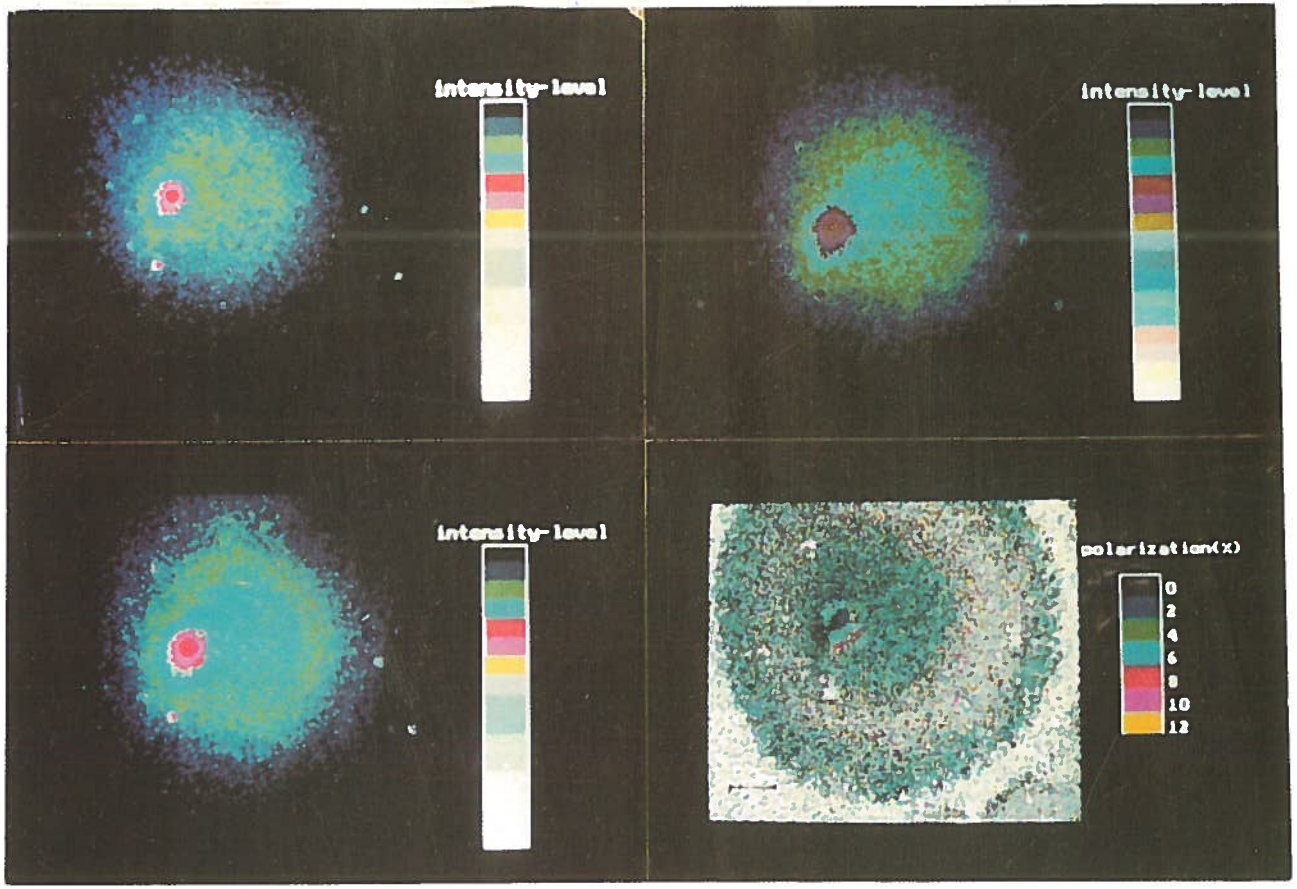
$$V = 234 + 2.4 \times 10^{-3} T \quad \ldots (2)$$

From this it is possible to assess that if the radio brightness temperature of the Sun falls to 1.75 x 10^4 °K or less, there will be no plasma flow. This also proves that the solar wind velocity value should be $\geq$ 276 Kms/sec. This analysis is based on a very limited data set. However, it seems to provide useful information about the plasma acceleration and hence it should be carried out for a large data base. This work has been done in collaboration with Himanshu Yadav of Gujarat University.

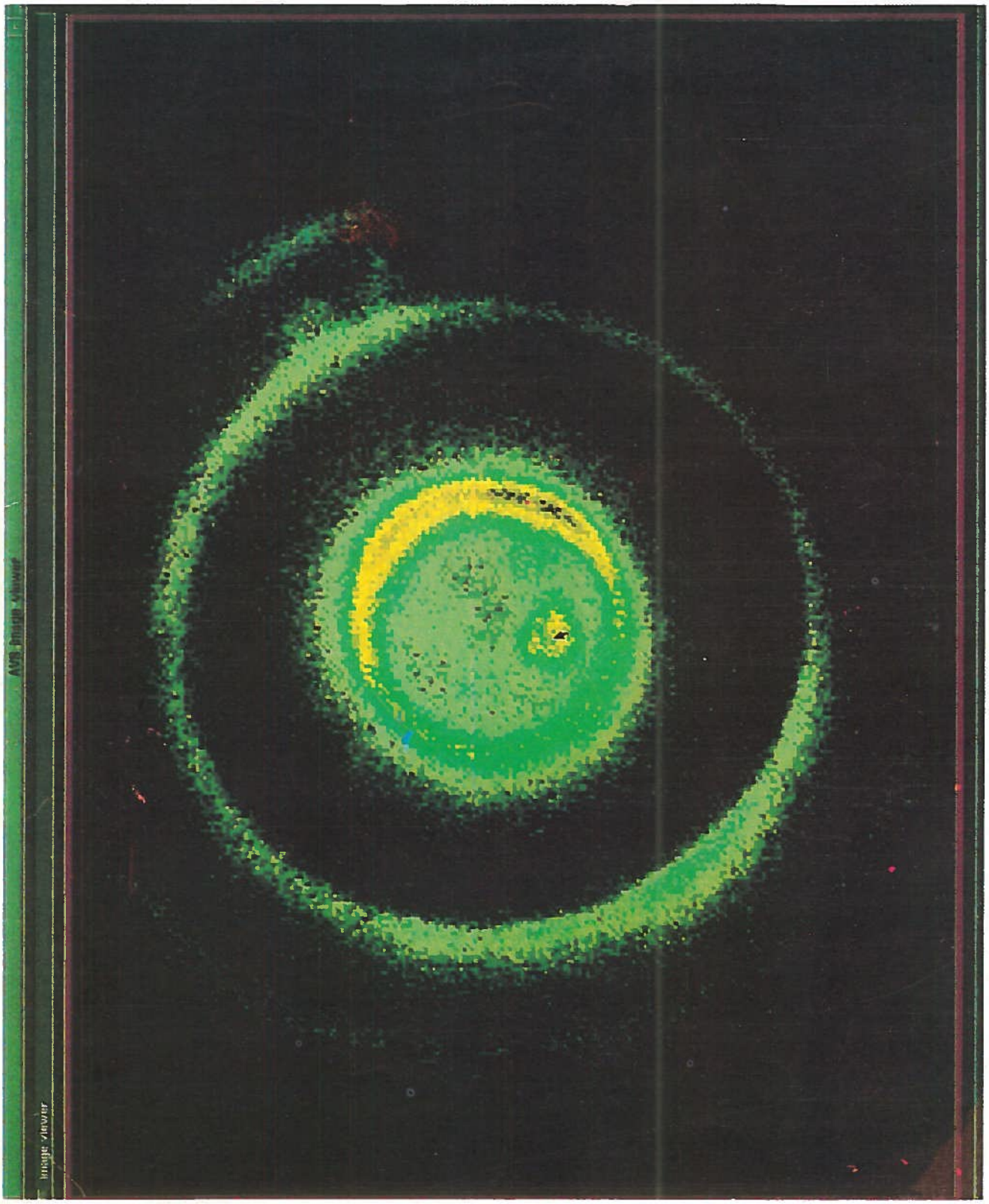
(H.O. Vats).

Radio Star and Satellite Scintillation by E-region Plasma Irregularities

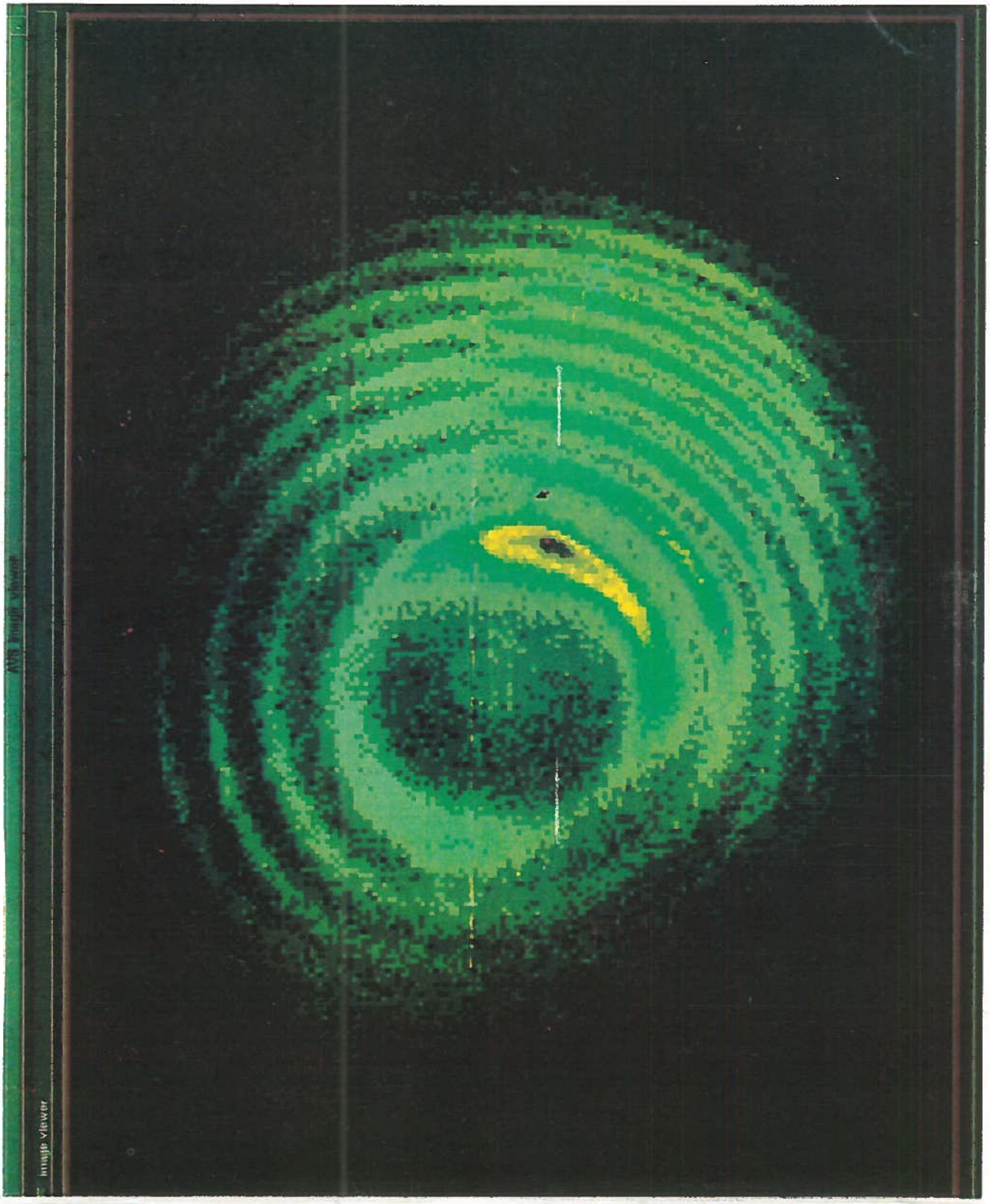
A case study of E- region plasma irregularities at low latitude from a set of simultaneous observations on June 3, 1993 was carried out. The ionospheric plasma irregularities are known to affect the propagation of HF and VHF waves. The observations used in this study are (i) 103 MHz signal of a radio star 3C 196 recorded by two large array telescopes located at Ahmedabad and Rajkot with a separation of about 200 Kms, (ii) 244 MHz radio beacon of Fleetsat satellite (geostationary at 73° E) recorded at Ahmedabad and (iii) ionospheric vertical sounding experiment at Ahmedabad. These observations provide several useful parameters and characteristic features of the plasma irregularities. The sub-ionospheric points to the radio source and to satellite are separated by about 40 Kms at E-region height. These observations also provide information on the dynamics of these irregularities. The calculations indicate largely a southward motion with a very small component toward west in this case. The drift speed of ~ 60 m/sec is calculated from the high



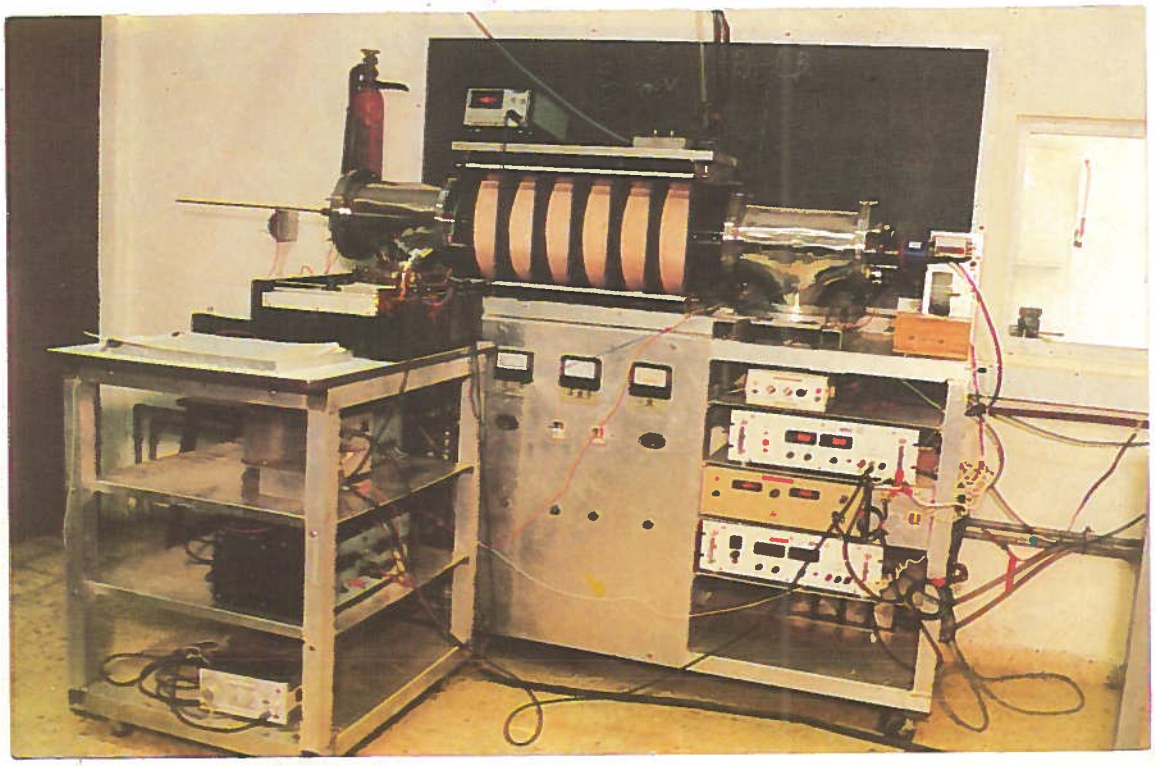
1.12 Comet Austin polarization image is shown along with the three images taken with three orientations (0°, 120° and 240°) of a polaroid sheet fixed in front of the 14 inch Celestron telescope. Polarization image in the lower right corner has been generated with the three images . shown in the figure. The line marked on the lower left corner of polarization image corresponds to linear distance 50000 km on projected comet image.



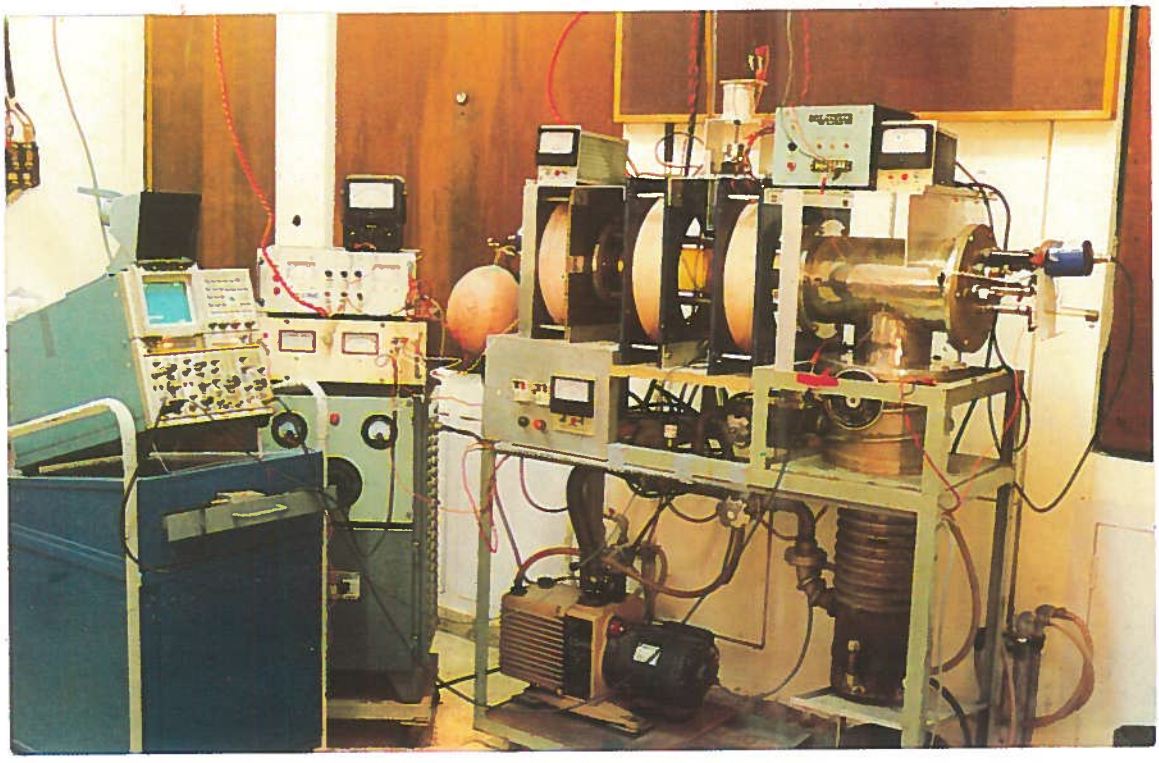
i.13 [NII] 6584 A interferogram around the Trapezium complex (see the arrow) in the Orion nebula obtained by the Imaging Fabry-Perot Spectrometer at 2.34 m VBT.



1.14 Prominent high-velocity flow probably coming from the star H36(07V) in Lagoon Nebula (M8) found in the [NII] 6584 A interferogram (seen as a bridge between the innermost and its adjoining fringes as shown by the arrow).



Experiment to verify the existence of discrete energy states in a classical mechanical domain



Dusty Plasma Experiment

frequency roll off of the scintillation spectrum at 103 MHz. Most of the scintillating power is confined to frequency range of 0.02 to 0.3 Hz with a high frequency roll off at 0.06 Hz. The irregularities within the patch are found to be in the range of 200 m to 3 Kms. The irregularities have power law distribution with index ~ 3.2. The scintillation during this event was very large with scintillation index $\simeq$ 1.18.

(H.O. Vats, H. Chandra, M.R. Deshpande, G.D. Vyas, K.J. Shah and C.R. Shah).

OPTICAL AND INFRARED ASTRONOMY

Imaging Polarimetry of Comet Austin

Imaging polarimetry on comet Austin was carried out during April and May 1990 when its phase was between 106 and 110 degrees. The results show that there are pockets/blobs of high and low polarization. In order to study the motion of such blobs (which are connected with nuclear jets) and dust dynamics (synchrones and syndynes) repeated imaging polarimetric observations have been made on comet Austin on several nights. Images were recorded on a photographic emulsion and the digitization work done on PDS machine at IIA. The polarization map for April 30 (Fig. 1.12) shows regions of high and low polarization nearly symmetrically distributed about the nucleus. The overall polarization is low and Austin appears less active on polarization map compared to comet Halley. No unusual activity in the form of jets is seen in the polarization map. The polarization is low near the nucleus and high (~ 16%) in the outer region (at about the mean distance of 190,000 km on west side), suggesting segregation of grains.

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

Velocity Field Structure in H II Regions

Continuing our efforts in understanding the velocity fields in the H II regions associated with star formation, we have made some fresh observations on Orion (M42) nebula in the [N II] 6584 A line (Fig. 1.13) using the Imaging Fabry-Perot Spectrometer (IFPS) on the 2.34 m Vainu Bappu Telescope of IIA at Kavalur. A set of six interferograms has been obtained around each of the stars θ^1 Ori and θ^2 Ori, covering a field of view of 2.5 arc min and one free spectral range. The velocity resolution is about 20 km/s and the spatial resolution is 1-2 arc sec. These observations are made with a view to understand better the kinematics of the ionization front on which we have already obtained some results (reported last year) in the [O III] 5007 A line. The analysis is in progress. Further, we have made observation on the Lagoon (M8) nebula in the [N II] line at the VBT. The preliminary analysis of the data shows a prominent high-velocity flow close to the ionizing star H 36 (07V) (Fig. 1.14). Such flows are usually attributed to either flows from young stellar objects or Herbig-Haro objects. The accretion disc formed around the equatorial regions of the rotating protostellar objects forces subsequent mass loss in collimated jets through polar regions. Detailed analysis is being done.

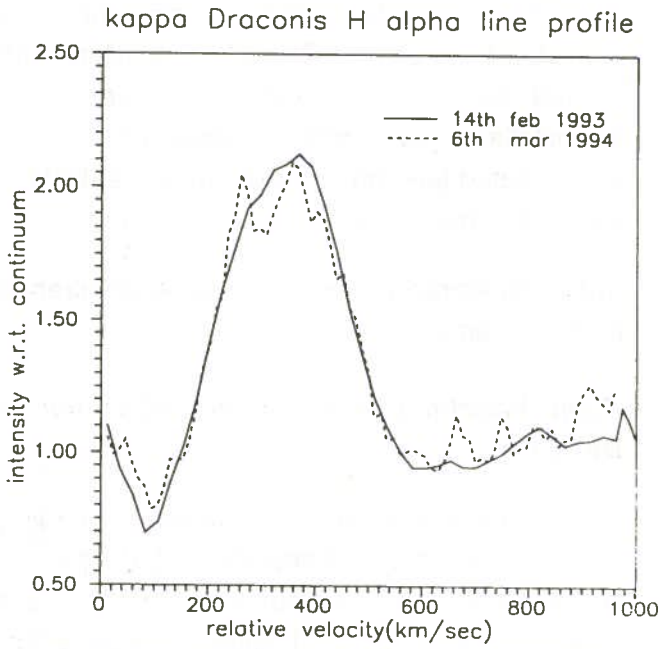
(B.G. Anandarao, D.P.K. Banerjee, A. Chakraborty and P. Seema)

Rapid Variability of Emission Line Profiles in Be Stars

High-Resolution (resolving power = 10^4) Fabry-Perot Spectrometric observations on a selected sample of Be stars are continued on the 1.2 m telescope at the Japal-Rangapur Observatory, near Hyderabad in collaboration with the

astronomers of the Astronomy Department, Osmania University, Hyderabad. The aim of these observations is to establish the minute-scale variability in the emission lines such as H alpha, He I 5875 A lines in Be stars. In general, such rapid variability, if confirmed, cannot be explained by rotating inhomogeneities or non-radial pulsations. They can only be explained, perhaps, by some rapid mass loss process induced by localized magnetic fields. One does not quite understand the process yet. Quite obviously this programme requires a large data base and hence the current efforts will be continued for some time.

One interesting observation that needs to be mentioned is on the star κ Draconis (B6 III). Our observations of H alpha emission on this star shows that the line profile changed from normal single- peaked structure to a triple-peaked one in a time period of less than one year (Fig 1.15). Usually the triple-peaked profile signifies fresh mass loss or the beginning of the shell-phase. We believe therefore, that the star may soon go into the shell-phase. Further observations on this star would be very important. Attempts are also being made to generate theoretical model emission line profiles to understand the observed triple-peaked structure.



1.15 H alpha emission line profiles from the Be star κ Draconis, showing variability in their structure.

(B.G. Anandarao and A. Chakraborty)

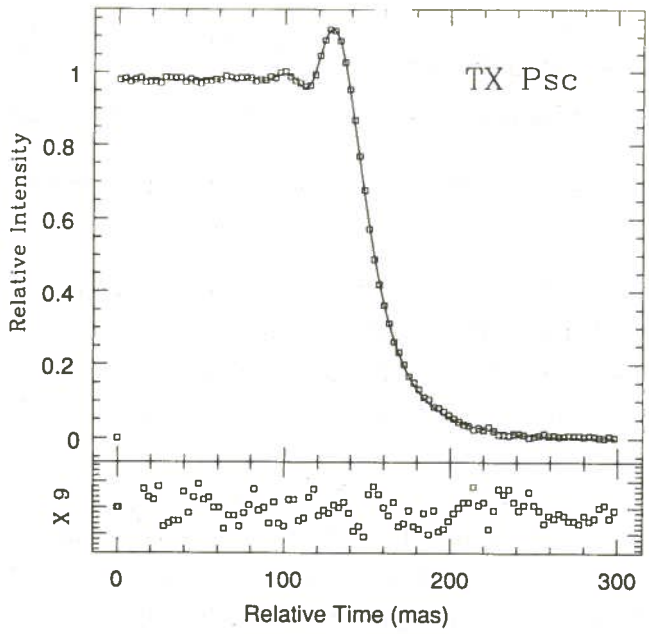
High Angular Resolution Studies at 2.2 Microns by Lunar Occultations

The program of observing lunar occultations of bright Infrared sources has been in progress for the last few years at PRL and several high quality occultation light curves in the K band (2.2 microns) have been obtained. As lunar occultation is a model-dependent technique, detailed modelling taking into account various instrumental effects, observational parameters, varying background level and scintillation noise is essential to recover the source brightness profile.

Detailed data reduction has been carried out for 11 out of 14 observed light curves. Occulted sources are well resolved in four of these analysed light curves. Uniform disk angular diameter is determined for these sources. We have not detected any binaries in the infrared light curves. Upper limit on the magnitude of the undetected secondary components, if any, are estimated from the signal and noise values of our light curves.

In what follows, we summarise results obtained on a carbon star TX Psc and the late type giants IRC 20200 & IRC 10578. In both cases no binary nature is evident from our light curves.

Carbon Star TX Psc: With the new fast photometer lunar occultation observations in the K band (2.2 microns) were continued at the 1 m, 2.3 m and 0.75 m telescopes of Vainu Bappu Observatory at Kavalur. Notwithstanding the rather poor

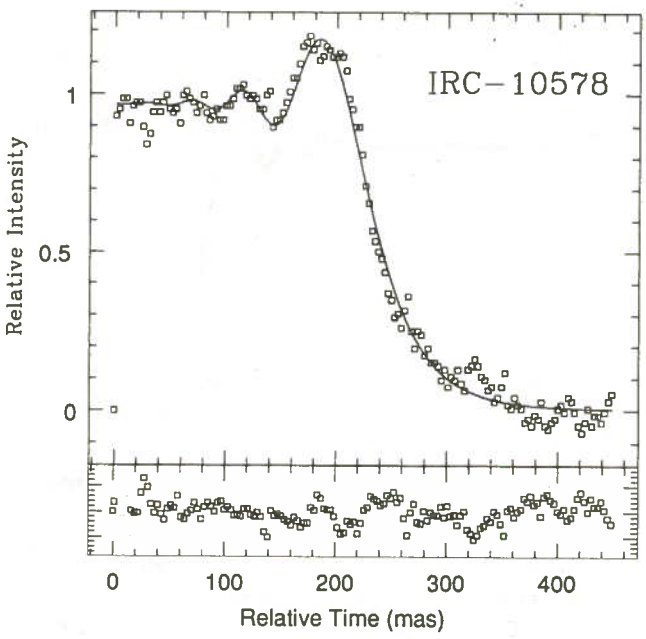


1.16 Lunar Occultation trace at 2.2 micron of the carbon star TX Psc obtained with the 1 m telescope at Kavalur on 13 February 1994. Strong gradients due to sky emission have been subtracted from the data. The derived angular diameter from the best fit to the data is 10.1±0.3 milliarcseconds.

observing conditions encountered at Kavalur during the year, the occultation of the carbon star TX Psc was successfully observed in February 1994 at the limit of telescope accessibility. Fig. 1.16 shows the data obtained and the model fit to the data. The steep sky gradients have been subtracted from the data. The model is based on a non-linear least square analysis. Apart from the scaling parameters to the light curve like the mean signal level before the occultation and the velocity component of the moon in the direction of occultation, the model also incorporates the exact time response of the detector measured earlier in the laboratory, the averaging effects of the finite telescope aperture and the optical bandwidth of the filter used. A value of the angular diameter of 10.1 ± 0.3 milliarcseconds (mas) has been obtained from the best fit to the data. In comparison, the earlier TX Psc observation made at Gurushikhar at a different position angle separated by ~ 35 degrees yields a lower value of 7.5 ± 1 mas. It appears from the two observations that we may be seeing some real asymmetry in the source structure or some pulsational variability of the source size. Further observations are needed to consolidate the picture.

IRC 20200 : This bright K5 giant was observed under good sky conditions with 1.2 m telescope at Gurushikhar during March 1991. The distance to the object is estimated to be 120 pc.

Fig. 1.17 shows our occultation data (dots) along with the best model fit (line) to the data. A linear fit was essential to account for the varying background light level. We obtain a value for the angular size of the source as 3.0 ± 0.3 mas. Using



1.17 Occultation trace of IRC+20200 observed at 1.2 m Gurushikhar telescope on 25 March 91 at 2.2 microns. Sky conditions were good. System performance was optimum and very good S/N on the fringes could be obtained. The lower trace is the difference between model and the data magnified five fold.

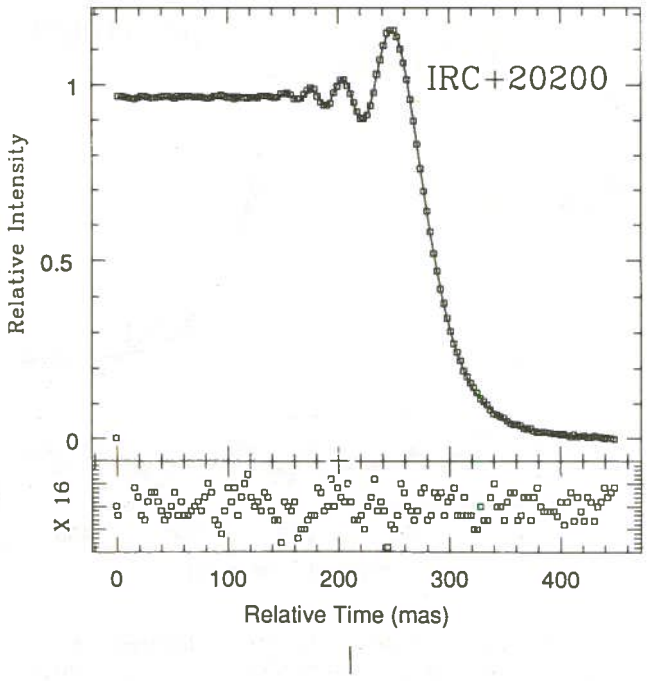
this value and photometric values available in the literature, we derive the stellar effective temperature, as T_{eff} = 3545 ± 120 K. From S/N consideration we put an upper limit to the binary (if any) brightness of ~ 6.7 magnitudes in K band.

Our results on the angular size and the multiplicity of this source are consistent with earlier infrared and optical occultations and speckle observations.

IRC -10578 : The occultation of G8 III-IV star marked the beginning of near infrared occultation observations from Gurushikhar during November 1990. This source had not been observed before, with any high angular resolution technique. The distance to the source is estimated to be 26 pc.

Fig. 1.18 shows our data alongwith the best model fit. We obtain a value of 6.9 ± 0.6 mas for the angular diameter following detailed recent analysis of the light curve.

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

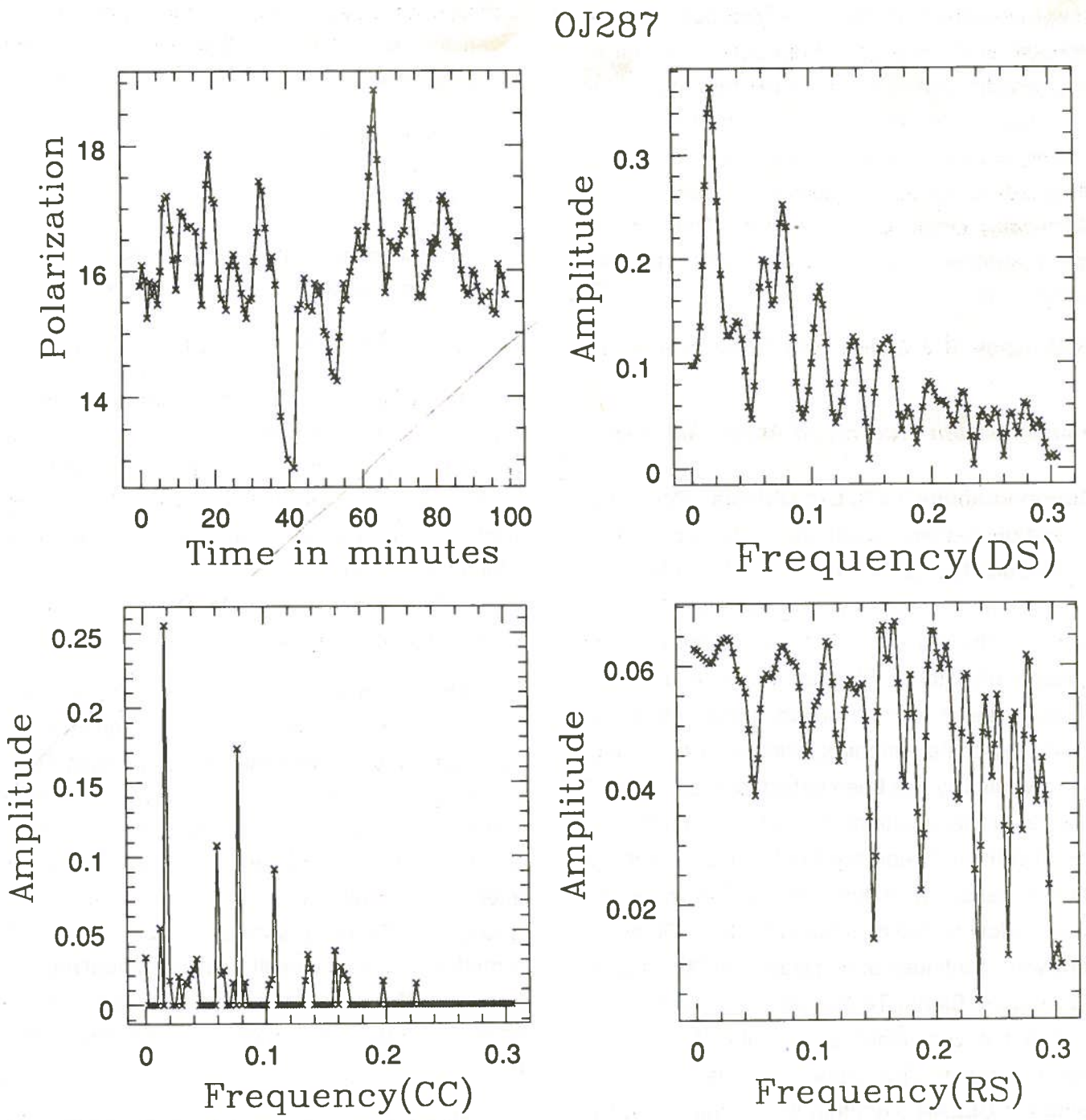


1.18 Occultation trace of IRC-10578 observed at 1.2 m Gurushikhar telescope on 25 November 1990 under good sky conditions. This occultation was one of the earliest IR occultations observed by the PRL group.

Optical and Near IR Studies of Eclipsing Binary Stars

Photometric study of apparent light variations of eclipsing binary systems can be profitably used to obtain information about the masses, luminosities, temperatures and relative dimensions of the component stars. These are fundamental parameters needed either as input parameters in the stellar structure models or to understand the process of stellar evolution. We have started an observational programme to study some of these systems in optical and near IR bands extending from 0.4 to 2.2 microns.

Serpentid Binaries : The Algol Binary Systems consist of a lower mass giant and a higher mass main sequence star. It is now a well-understood fact that the lower mass giant was initially more massive and evolved faster to become a giant. At this stage a substantial amount of mass is lost and it becomes less massive while the initially less massive component becomes more massive by capturing some of the mass lost by its companion star. It is very important to obtain observations of the mass transfer phase. However, as the mass transfer rate is large the duration of this phase is small compared to the overall life time of the binary system. The Serpentid binary systems are currently believed to be systems in the so called rapid mass transfer phase leading to Algol systems. Due to the high rate of mass transfer, often, circumbinary rings or discs are seen. In some systems, the gainer is embedded in an optically thick disc at lower temperature leading to shallow secondary eclipse depth at optical wavelengths. For such



1.19 Microvariability (~ 6 min) in the BL Lac object OJ 287.

cases it would be very interesting to observe the system photometrically both in the optical and near IR wavelengths as the secondary eclipse depth will increase when one goes from optical to near IR wavelengths, thus obtaining more information about the nature of the cooler component. Preliminary observations at optical wavelengths have been obtained using 35 cm telescope and thermo-electrically cooled CCD detector. The detailed optical and near IR photometry will be done in the coming years.

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

Active Galactic Nuclei and Active Galaxies

Micro-variability in BL Lac Objects : Polarimetric and photometric observations were continued for BL Lac objects: OJ 287, OI 90.4 and Mrk 421 on 2.34 m Vainu Bappu Telescope of IIA at Kavalur. The aim is to find the nature of rapid optical variability in BL Lac objects and AGNs. Although there is keen observational interest in short time scale variability, such data is lacking. Micro-variability has been detected in OJ 287 and Mrk 421 in observations carried out on January-March 1991 and February 1992. The observations showed variability in flux and polarization in time scale as low as 6.3 minutes in OJ 287. Observations were continued during March 10-20, 1993 on 2.3 m Vainu Bappu Telescope. The observations confirm the very small time scale of variability detected earlier. The Fourier analysis of the data using the CLEAN algorithm shows the existence of variability time scale as low as 6 min (Fig. 1.19).

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

Star Formation Study in Markarian Galaxies : A lot of attention was given to nuclear activity in galaxies in the past, while not much attention was given to the host galaxy. Some very important questions are to be addressed. For example:

i) How the star formation rate in Seyferts compares with the star formation rate in normal galaxies?

ii) Are the recent star formation regions localized in special places in the Galaxy?

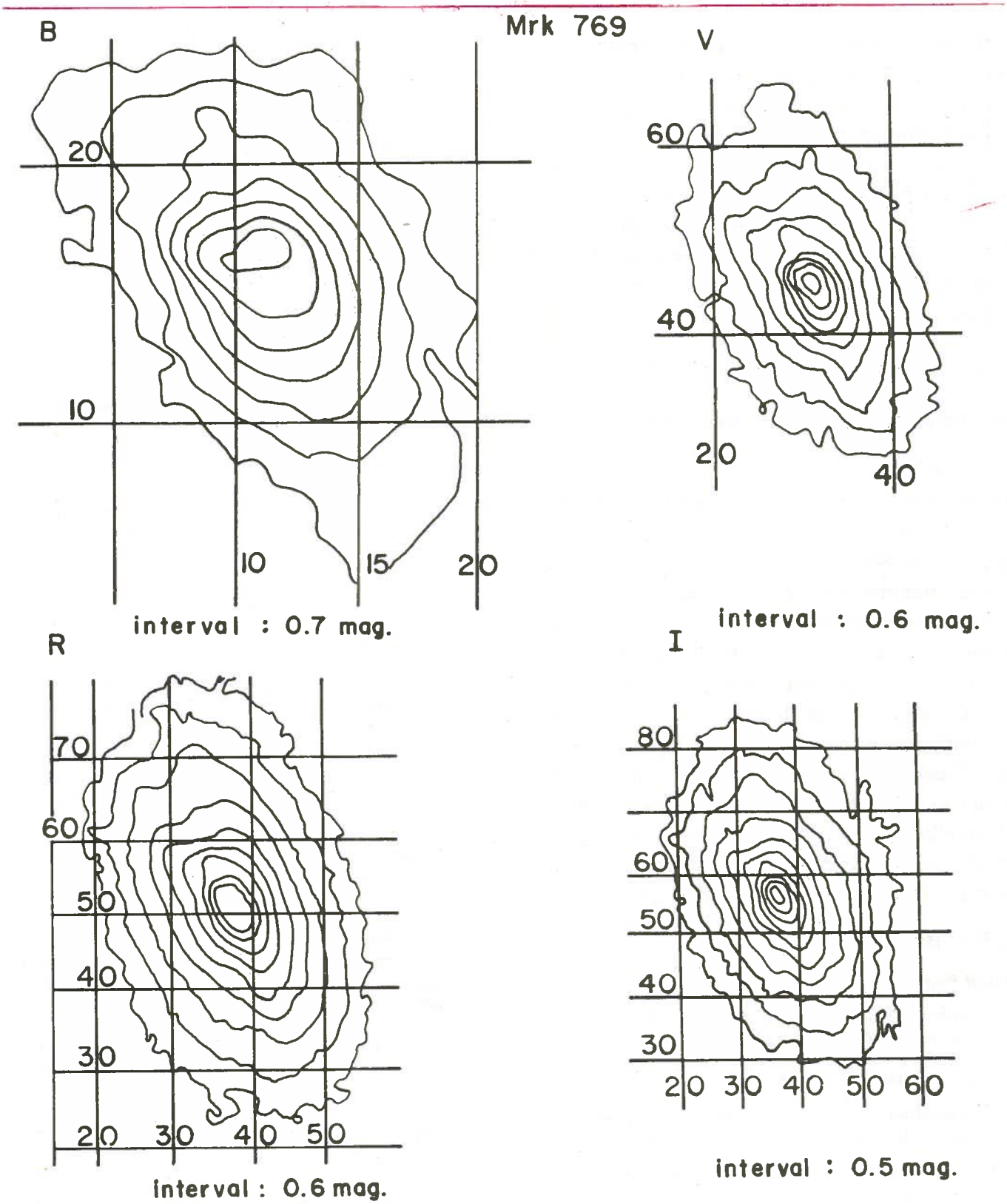
iii) Have these regions particular properties?

These and other questions are important in order to understand the relationship between nuclear activity and star formation. To address these questions, broad band (UBVRI) imaging work has been initiated on Markarian Galaxies which have large 60 micron flux. There are plans to extend this work to near IR imaging when IR array becomes available.

About a dozen galaxies have been observed and the analysis work has been completed on some galaxies. The analysis was done using IRAF package on SUN work station at U.P. State Observatory. Fig. 1.20 shows the contour maps of BVRI and colour images of the galaxy Mrk 769. An interesting result has been found in Mrk 769 galaxy: the (B-V) map shows a region of high star formation which is quite off from the central region. This indicates that the active star formation in active galaxies is not necessarily confined to the nucleus.

This work is being done in collaboration with scientists of U.P. State Observatory, Nainital.

(U.C. Joshi)



1.20 Contour maps of Mrk 769 in BVRI bands. B contours : 17.7 - 21.9 mag. ; V contours : 17.0 - 21.8 mag : R contours : 16.5 - 21.3 mag ; I Contours : 16.5 - 21.0 mag.

Astrophysical Investigation with IR Polarimetry

This is a DST-funded project aimed at developing an Infrared polarimeter in PRL to study primarily the star formation regions. This instrument was designed and fabricated in PRL and the laboratory tests were carried out. The instrument is functioning satisfactorily under laboratory test conditions and as soon as our telescope becomes available, the instrument will be tested on the telescope and observations can be started.

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

On the Accuracy of the Caustic Test

The Caustic or Gaviola test, used for the testing of mirrors, has been studied with reference to the work of Schroader (ATM-III, 1953, Ed. A.G.Ingalls, Scientific American). It is found that the two important formulae on which the results of the test are interpreted may be represented, for more accurate results, by an alternative pair of equations. It is seen that the use of these alternative equations leads to improved precision in evaluating mirror surface quality. Their applicability is found to be specially necessary for mirrors which are either large or have small focal lengths or have both these properties. This work is being done in collaboration with Prof.R.V.Willstrop of the Institute of Astronomy, Cambridge University.

(D.P.K. Banerjee)

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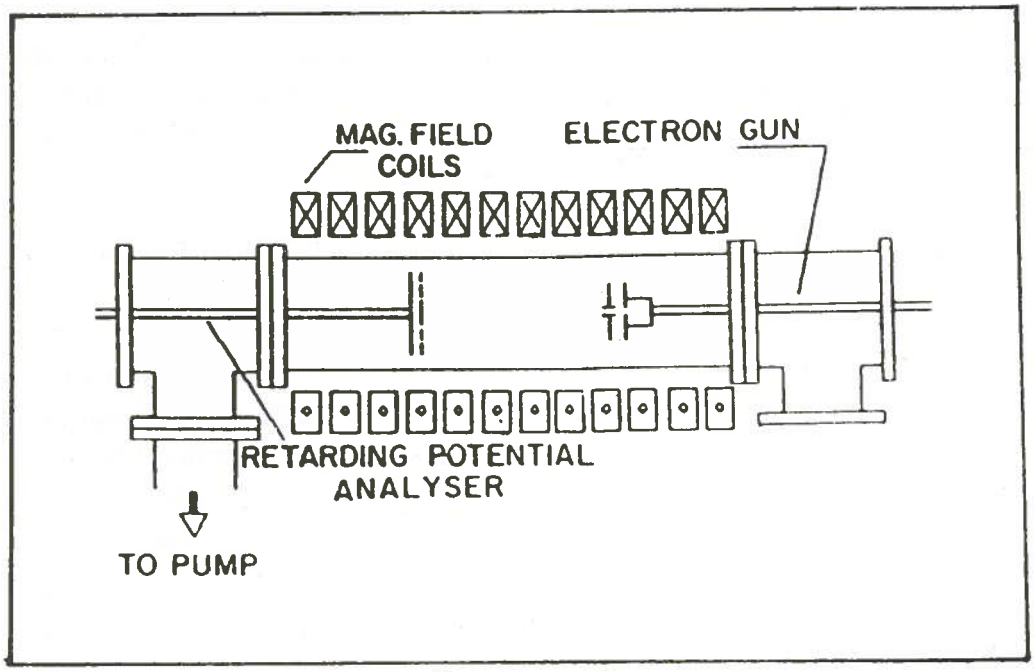
BASIC PHYSICS LABORATORY

Observation of Discrete Energy States in a Classical Mechanical Domain

Continuing with the experiments on the observation of the existence of discrete energy states in a domain of parameters belonging to the classical mechanical regime, we have new results, demonstrating interesting effects when the energy of the electron beam, injected into a magnetic field is scanned over a wide range. Electrons from an electron gun with a low beam current ~ 0.1 μA are injected from one end of an SS vacuum chamber (3m long and 0.27 m in diameter, evacuated to 5×10^{-7} torr) permeated by an axial magnetic field, with a small pitch angle (< 5°). At the other end of the chamber is a Faraday cup, which can be moved along the axis of the chamber so as to vary its distance from the gun. As the gun is switched on in a steady continuous operation with a certain electron energy, with a sufficiently strong magnetic field (more than 100 G), all the electrons leaving the gun are collected by the collector-plate-grid system.

In our earlier reported experiments Fig. 1.21 we had injected electrons with a fixed energy into a magnetic field and when the potential on the grid is swept from a large negative value to zero, both the currents reaching the plate and grid were found to exhibit an oscillatory behaviour instead of decreasing monotonically to zero, as would be expected from the standard Lorentz equation of motion. In the present experiments we have studied the behaviour of an electron beam when its energy i.e., the cathode voltage is swept from a large negative value to zero while both the collector plate and grid are kept at the ground potential. Both the plate and grid currents, recorded as the cathode voltage is dropped from - Φ_c to zero, exhibit a number of pronounced maxima and minima, whose separation is found to increase monotonically with the cathode voltage. The maxima and minima in the two profiles occur in such a manner that they are almost in anticorrelation with each other.

The plate and grid currents were added up to check whether they cancel out each other and it is found that even after adding the two, there is a net oscillatory behaviour. In order to rule out the possibility that the oscillatory behaviour of the current profiles is caused by the grid in front of the collector plate, just the collector plate current was recorded after removing the grid in front of it. This current profile also exhibits an oscillatory behaviour similar in magnitude, as in the case when the plate and the grid currents of the detector were added together.



1.21 Schematic of the Experimental Device.

We have tried to trace the sink for the missing electrons (corresponding to the dips) by simultaneously measuring the anode and cathode currents of the electron gun. While the cathode current is found to monotinically decrease to zero as the cathode voltage is dropped to zero, the anode current profile is found to exhibit a number of minima which are out of phase with the added plate and grid currents. Though we are still not clear about the mechanism, responsible for the oscillations in the independently recorded plate and grid current profiles to be more pronounced (as compared to the profiles obtained with just the collector plate without the grid in front of it) we may still conclude that the missing current corresponding to the forbidden states is actually led to find its way as the anode current to the ground.

We have attempted to fit the energies E_j, corresponding to the dips in the relation

$$E_j = \frac{1}{2}m\left[\frac{\Omega L}{2\pi}\right]^2 \Big/ \left[j+\frac{\phi}{2\pi}\right]^2$$

with E_j being the energy of the state j designated by an integer j, a 'quantum number' for the state. We clearly see that the 'quantum' numbers j for the series of dips do differ by unity for the consecutive dips in the profiles.

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

Dusty Plasma Experiment

A dusty plasma experiment has been designed and set up to study basic phenomena like charging and confinement of dust grains. Dusty plasmas are low temperature ionized gases, which contain charged particulates of micron and submicron size. These plasmas have important applications in the study of planetary rings, magnetospheres, cometary tails and earth's ionosphere.

Of late considerable efforts have been made to investigate dusty plasmas theoretically and effects like charging of dust particles, wave phe-

nomena, instability and scattering of electromagnetic waves have been elucidated. However, as far as laboratory experiments on dusty plasmas are concerned, there are only a few attempts so far, which are still in their initial stages and in this sense it is virtually an unexplored field.

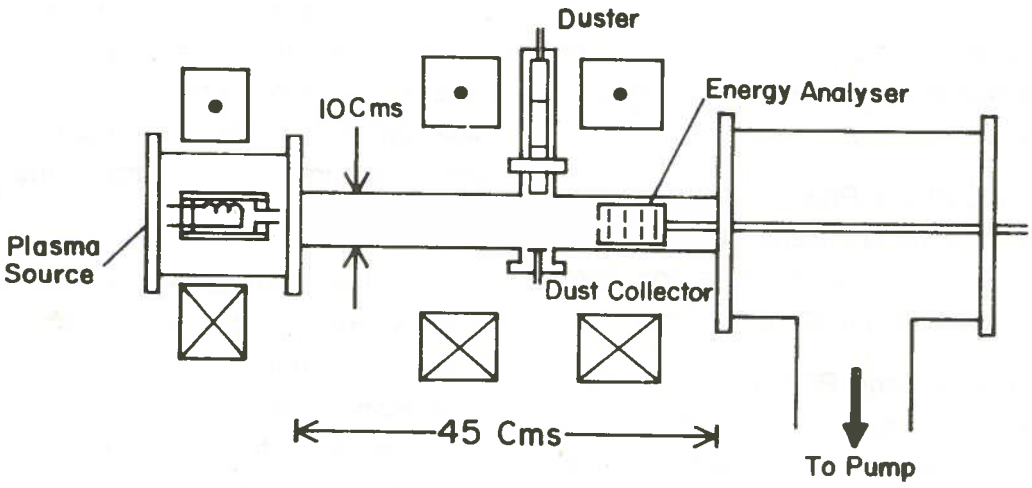
We have designed and set up a pulsed experiment in a linear machine to investigate the characteristics of charging of dust grains and their confinement against gravity (Fig. 1.22). A steady state nitrogen plasma flow, about 5 cms in diameter, is produced in a cylinderical glass chamber about 50 cms long and 10 cms in diameter, evacuated to 5×10^{-6} torr., with the help of a plasma gun of PIG type, located at one end of the chamber. External DC magnetic field, applied along the axis of the glass tube, is produced with the help of two coils mounted coaxially in helmholtz configuration. Plasma densities of 10^{10} per c.c. are obtained.

The dust is introduced into the plasma from a dust chamber consisting of a s.s. vacuum bellow and a number of fine sieves. A thrust given to the bellow, using an electric hammer, injects the dust particles through the last sieve into the plasma. Aluminium oxide is used as dust with 30 microns as the upper limit of particle size. A detector plate, mounted vertically below the dust chamber, is used for registering the charged dust particles. The other diagnostic elements include an electrostatic energy analyser mounted at the other end of the glass chamber and a Langmuir probe. The currents collected by the probe in the absence and presence of the dust are compared. Energies of electrons and ions are estimated using the energy analyser. Preliminary results have been obtained with this experimental set up.

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

List of Publication during 1993-94

R.K. Varma and A.M. Punithavelu, Behaviour of charged particle motion in a magnetic field and retarding potential II - Observations of the existence of "Forbidden states" and Aharanov-Bohm analog in classical mechanical domain, Modern Physics Letters, **A8**, 3823, (1993).



1.22 Schematic of the Dusty Plasma Device.

PLANETARY ATMOSPHERES AND AERONOMY

As in the past, the activities of the Planetary Atmospheres and Aeronomy Division cover the gamut of physics and chemistry of the different regions of the earth's atmosphere and as well as other planetary and cometary atmospheres. The investigations cover a wide range of activities including in situ balloon and rocket- borne measurements and also remote sensing by means of optical and radio sounding techniques. There has always been a modest parallel attempt to form atmospheric models and to workout numerical simulations as well, in order to understand the complex processes that occur in the different regions of the atmosphere in a comprehensive manner.

There are three broad classifications under which the division's activities are reported - the classifications having been made on the basis of the dominant physical and chemical processes and also on the accessibility of these regions by different means/techniques. These are as under:

i) Laboratory Astrophysics - the activities of this subgroup refers to the laboratory measurements of absorption, fluorescence and scattering cross sections of a variety of species that are of aeronomic interest - whether it is in the terrestrial atmosphere or in planetary/ cometary atmospheres.

ii) Middle Atmospheric Phenomena - the emphasis here is on chemistry, radiation and dynamics of the region of the atmosphere starting from ground upto 80 - 85 km.

iii) Upper Atmospheric Phenomena - which deals with the region of the upper atmosphere above 85 km, and concerns with the processes in the ionosphere and neutral atmosphere including the structure, energetics and dynamics.

In the subgroup of Laboratory Astrophysics new experimental facilities have been specially built for determining the photo- absorption cross section of various species at different temperatures. The temperature dependence of these reaction rates are extremely important for any aeronomic calculations involving these species.

With the setting up of the Laser Laboratory for investigating laser induced reactions, determination of the characteristics of certain fluorescing materials like sodium salicylate both in the form of grained coating and solution was taken up and investigated both in the weak and strong laser fields.

In the subgroup of Middle Atmosphere, significant work has been done in the study of ozone chemistry, both in the troposphere and stratosphere. In the troposphere ozone acts as an effective green house gas while in the stratosphere it acts as a shield from the harmful UV radiation. Surface ozone variabilities get directly linked to many of the precursors of tropospheric ozone. In the stratosphere, detailed analysis of the cryogenically collected air samples from different heights have provided the vertical profiles of the trace gases that destroy ozone catalytically. The importance of gases containing Bromine and their possible origin have been estimated quantitatively. The development of an indigeneous cryosampler is another land mark.

Further detailed studies of Nitrogen oxide compounds that are relevant to ozone chemistry have been carried out with emphasis to NO_3 concentration and a steady state model for NO_2 has been worked out to understand the diurnal variability exhibited by this species. Another interesting observation is the large deviations in the estimated change in the total ozone column density presum-

ably due to Pinatubo volcanic eruption, at different locations calling for an indepth study of the causative mechanisms.

The other activity of the Middle Atmospheric subgroup is the aerosol study. Balloon-borne measurements of aerosol size distribution in the Pinatubo aerosol layer using sunphotometer which complemented by Lidar measurements had shown that the aerosol layer at 23 km nearly vanished by mid 1992 with an estimated decay time of 14 months. The infrared and visible data of INSAT, has also been used to estimate the annual loading of the atmosphere with desert aerosols, by devising a retrieval algorithm taking into account of all the relevant parameters.

In the branch of Upper Atmospheric Studies, results based on high resolution spectroscopic determination of thermospheric temperatures revealed the large variability exhibited by the neutral temperatures. While the background lifting is essentially controlled by the solar activity levels, the short term variabilities appear to be controlled by the geophysical processes peculiar to the region of measurements and these have been shown to have repercussion in the estimation of meridional winds based on ionospheric data.

There have been rocket experiments for the study of E and F regions of the ionosphere during daytime conditions. One of the significant observations, is that the calibration factor for converting the probe current to electron density is altitude dependent and the positive ion densities agree with the ground based radio probing technique within the limits of experimental uncertainty.

The unique Dayglow Photometer has provided a precursor to the occurrence of the equatorial spread-F (ESF) atleast three hours prior to its actual occurrence in ionosondes. The enigmatic problem of ESF and its day to day variability appear to be closely linked to the daytime Equatorial Ionization Anomaly(EIA).

Preliminary results from the RH-560 rocket launchings from SHAR for the investigation of the 'onset' conditions of ESF have become available. Presence of large scale gradients in the ambient electric fields around 180 km at the onset of ESF, presence of significant magnitude of vertically downward winds, and significant amount of neutral metallic atoms in the altitude range of 120 - 150 km are some of the highlights.

The nonlinear numerical simulation studies of equatorial spread-F have provided yet another important result, this time with regard to the amplitudes of the initial perturbation. It had been shown under favourable conditions, an initial perturbations even as small as 0.5% of background densities would suffice, for the creation of a plasma bubble within 1200 s.

This year the area had undertaken a new programme *Optical Aeronomy from Antarctica* to explore one of the unexplored phenomenon of *Daytime Optical Aurora.* A new daytime photometer with several novel features and multiple wavelength measurement capability has been built, installed and successfully operated from the Indian station 'Maitri' at Antarctica. These have provided the first continuous daytime auroral emission measurements.

Coming out of the terrestrial atmosphere, there have been theoretical studies to understand the processes associated with the photoelectron and secondary electron fluxes in the Martian

Ionosphere and also on the production and emission of carbon and oxygen in the inner coma of Comet Halley.

All these are presented in the following sections.

LABORATORY ASTROPHYSICS

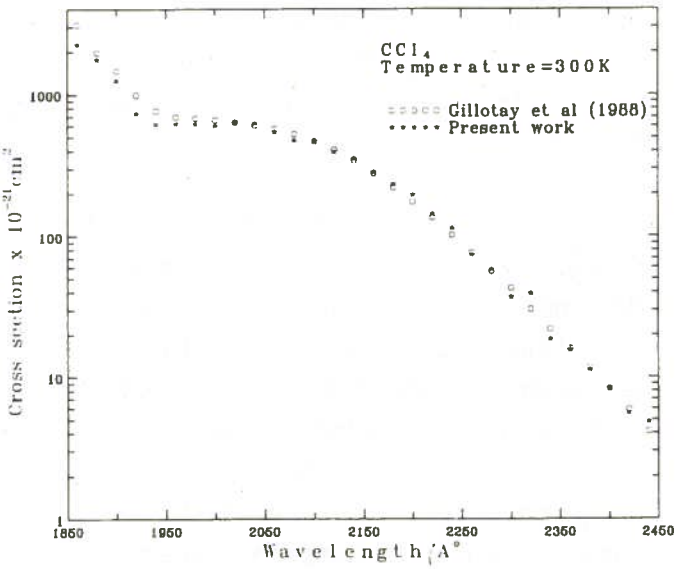
Photoabsorption Cross Section Measurement of Carbon Tetrachloride

Photoabsorption cross sections for carbon tetrachloride have been measured in the 185-240 nm spectral region at room temperature. Measurements have been made with an instrumental resolution of about 0.1 nm and an overall accuracy of better than ±5%.

A new experimental set up has been designed and fabricated in the laboratory to make such measurements. It consists of an argon mini-arc light source giving a continuum from 110 to 350 nm, a one-meter near normal-incidence asymmetrical type concave grating monochromator, a beam splitter to monitor photon beam intensity during the experiment, the absorption chamber whose length could be varied from 70 to 90 cm as desired, the cooled photomultipliers operated in the counting mode and proper amplifiers and fast data acquisition system. The absorption chamber is fitted with two long quartz tubes at its two ends and these could be moved in and out to take care of the length of the chamber. These tubes are closed at the outer ends by suprasil quartz plates. The absorption chamber is fitted with a cold bath and the temperature of the bath could be varied from 200 to 300 K.

The photoabsorption cross sections for carbon tetrachloride have already been measured at room temperature and similar measurements are being carried out at other temperatures between 200 and 300 K. At room temperature, absorption cross sections obtained in the present work in the wavelength region, 185 to 195 nm, are smaller in value by 20 to 30% as compared to those reported by other researchers. At wavelengths larger than 195 nm and upto 240 nm, the photoabsorption cross sections are comparable within the stipulated experimental errors (Fig. 2.1).

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



2.1. Photoabsorption cross section for carbon tetrachloride at room temperature.

Fluorescence Studies of Sodium Salicylate in Weak and Strong Laser Fields

Fluorescence spectra of sodium salicylate solution as well as fine grained coatings have been studied at incident photon wavelengths of 253.7 nm (HgI) and laser lines 193 nm (argon fluoride) and 308 nm (xenon chloride) under weak field conditions. Similar investigations have also been carried out at 193 and 308 nm lasing wavelengths under strong laser field conditions.

The experimental set-up includes the excimer laser/mercury lamp, the beam expander for producing weak laser fields and proper lens combination for focussing laser beam so as to create strong laser field conditions, sodium salicylate solution in quartz housing or fine grained coatings on glass substrate, a bifurcated quartz optical fibre bundle, a 0.5-m Czerny-Turner type monochromator, a photomultiplier and a high sampling rate digital oscilloscope (for laser beam experiment only). The experimental set up was designed and fabricated in the laboratory.

At 253.7 nm, the fluorescence spectrum for sodium salicylate solution extends from 350 to about 530 nm with a broad maximum around 410 nm where as for fine grained coating the whole fluorescence spectrum is shifted to higher wavelengths with the broad maximum at around 430 nm. At 308 nm, under weak laser field conditions, the shift in the fluorescence spectrum towards higher wavelengths in case of fine grained coating is much smaller as compared to that at 253.7 nm. Both at 308 and 193 nm, under strong laser field conditions, the fluorescence spectrum observed showed a very intense peak at about 405 nm superimposed on the usually broad continuum observed under weak field conditions. The spectra are being analyzed.

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

Multiphoton Ionization of Molecules

In the last year's annual report, it was discussed about taking up resonantly enhanced multiphoton ionization (REMPI) of molecules in the near future using excimer-laser pumped dye laser. In (n+1) REMPI processes, the ionization step itself can be described as one-photon process, if the n-photon resonant states have a life time long enough to allow an additional one-photon absorption. In case of molecules, the direct ionization should give rise to an intensity distribution governed by the Franck-Condon principle between n-photon resonant state of the neutral molecule and the final ionic states.

It was proposed to probe the so called "dark states" of the molecule which are optically forbidden for single photon absorption as the selection rules allowed in the case of single photon transitions are vitiated when multiphoton absorption takes over. To carry out such studies, a new experiment was designed last year and the fabrication of the system was started. During this year, the whole set up has been fabricated and integration of the different sub-systems have been carried out. It is felt that the experiment would become operational very soon. The first molecule chosen for investigation would be nitric oxide.

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

Laser Produced Plasma - A New Light Source

Laser produced plasma using plane targets includes the expansion plume region where its energy is converted from thermal energy to kinetic energy by adiabatic expansion in vacuum. The expansion plume is a source expanding radially and axially but of decreasing brightness. The rapidity of the expansion is such that recombination rates are too slow to bring the equilibrium with the decreasing temperature and therefore, the highly ionized ions persist in a "supercooled" condition. One could, therefore, observe line and continuum radiation from visible to x-ray region at different distances from the target. From a fraction of a millimeter to several millimeters from the

target, VUV emissions can be observed with electron density from 10^{18} upto 10^{21} cm^{-3} and temperature from 20 to 200 eV. This is the type of light source we intend to produce for carrying out photon impact atomic physics experiments in the wavelength region 120 to 200 nm.

Such a light source has already been designed and all its sub-systems have been fabricated in the laboratory. We hope to test the integrated system in near future and obtain the spectrum using an evacuated Czerny-Turner type of 0.5-m monochromator. This light source would be used to study the fluorescence spectra of weakly fluorescing system in the VUV region.

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

MIDDLE ATMOSPHERE

Tropospheric Ozone and its Precursors

Study of the tropospheric ozone has recently gained importance due to its role in the greenhouse warming. The tropospheric ozone is found to be increasing. The increase is attributed to increase in the levels of its precursors, such as oxides of nitrogen (NO_x), carbon monoxide (CO), methane (CH_4) and non- methane hydrocarbons (NMHCs). Due to large spatial and temporal variations in the concentrations of ozone as well as its precursors, it is not possible to make proper global estimate of this source of ozone. We have recently initiated a programme to monitor ozone and its precursors near surface at Ahmedabad, Gadanki (near Tirupati) and Mt. Abu to study the variability and trends in ozone and to study the variations in different eco- systems.

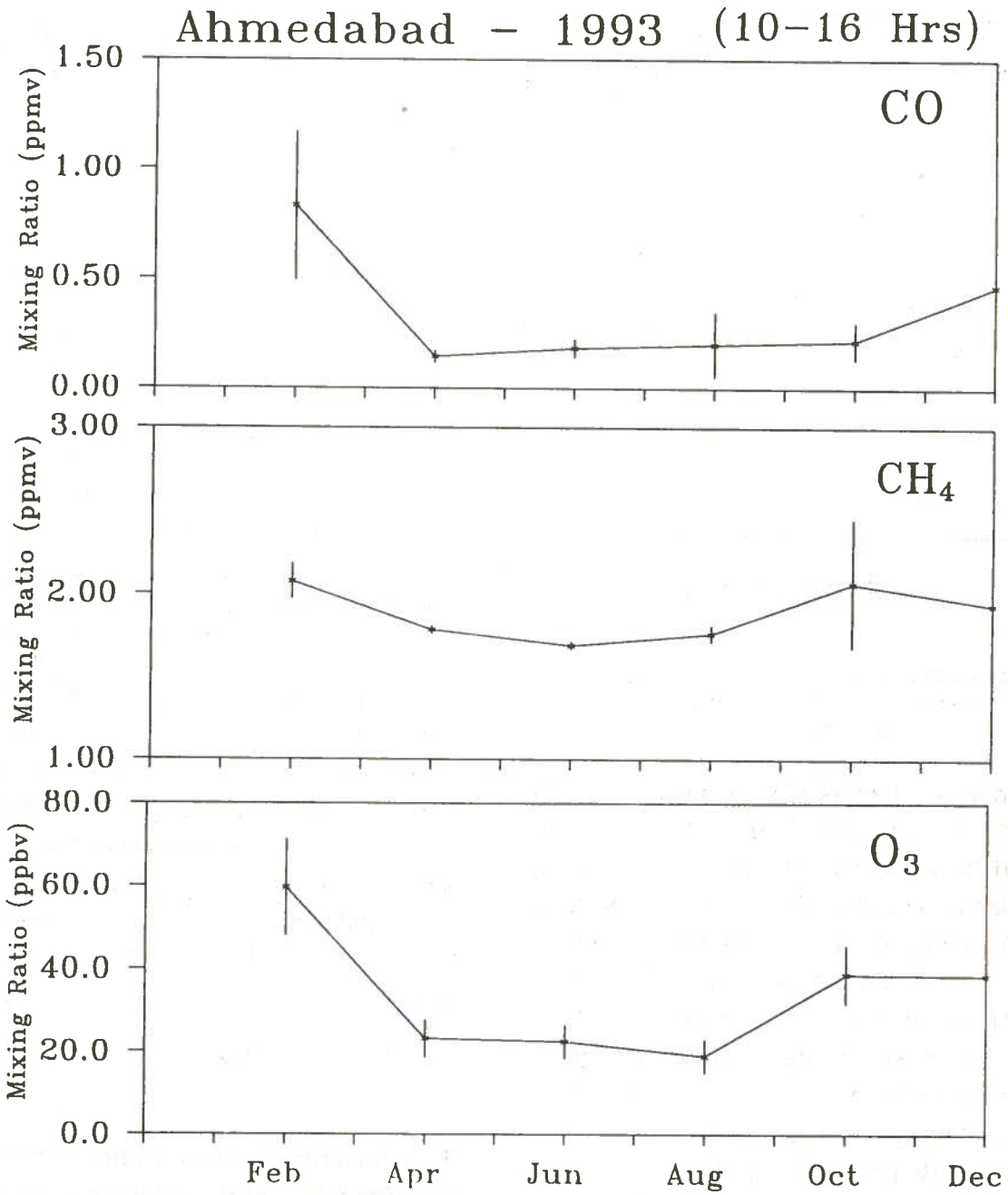
At Ahmedabad, surface ozone is being monitored continuously since November 1991. We have initiated measurements of NO_x using an automatic system since October 1993 at Ahmedabad. Measurements of CH_4 and CO are done in different months continuously for 72 hours using gas chromatographic technique. Fig. 2.2 shows average concentration of O_3, CO and CH_4 during noon hours (10-16 hours) measured in different periods. Higher concentrations of CO and CH_4 in winter months lead to higher concentrations of ozone.

Monitoring of ozone and NO_x has also been started at the MST Radar site, near Gadanki since December 1993. This site offers two special features - it is a rural site and vertical wind data using the MST Radar are also available. Information on the vertical wind together with ozone and NO_x measurements will be very useful in understanding the role of downward transport of ozone from the stratosphere. Fig. 2.3 shows average diurnal variation of NO_x at Ahmedabad and Gadanki for the month of January 1994.

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

Vertical Distribution of Trace Gases

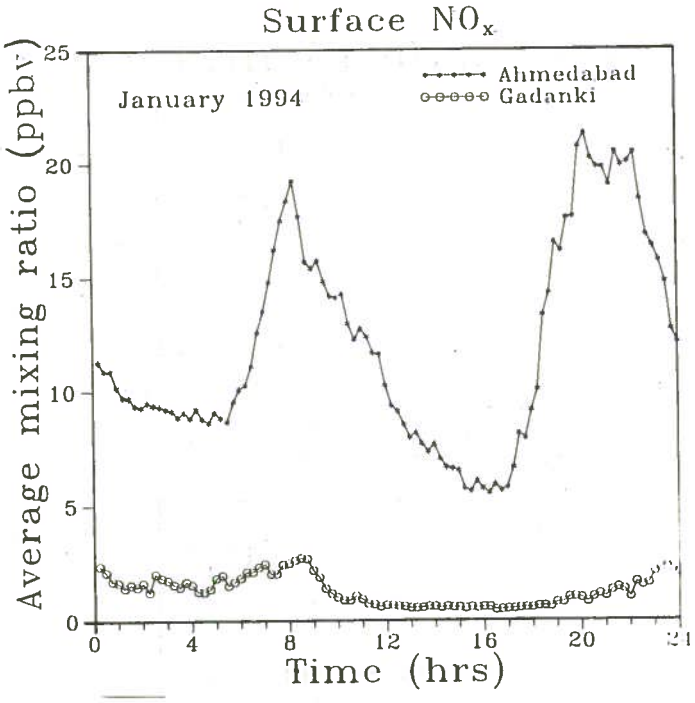
Depletion of ozone in the stratosphere is caused by catalytic reactions of various groups of radicals, such as HO_x, NO_x, ClO_x and BrO_x. The chlorine and bromine radicals are produced from the photolysis of the chlorofluorocarbons containing chlorine and bromine atoms. The ozone depletion potential (ODP) of the bromine containing molecules are 20 to 60 times more than the highest ODP of a chlorine containing molecule. This feature together with very high growth rates of some of the Halons (CFC- 12B1 and CFC-13B1) make bromine containing gases very important for stratospheric ozone depletion study. Methyl bromide (CH_3Br) is the major gas in the family of bromine containing gases. It is believed to be of



2.2. Average concentration of O_3, CO and CH_4 during the period of 10-16 hours in different months measured at Ahmedabad.

natural origin. However, recent measurements indicate anthropogenic sources of CH_3Br also. The first full profile of CH_3Br upto 27 km is obtained from the samples collected during a balloon flight launched from Hyderabad on April 9, 1990 jointly with the Max Planck Institute for Aeronomy, Lindau, Germany. It shows a sharp decrease in the mixing ratio above the tropopause height of 18 km.

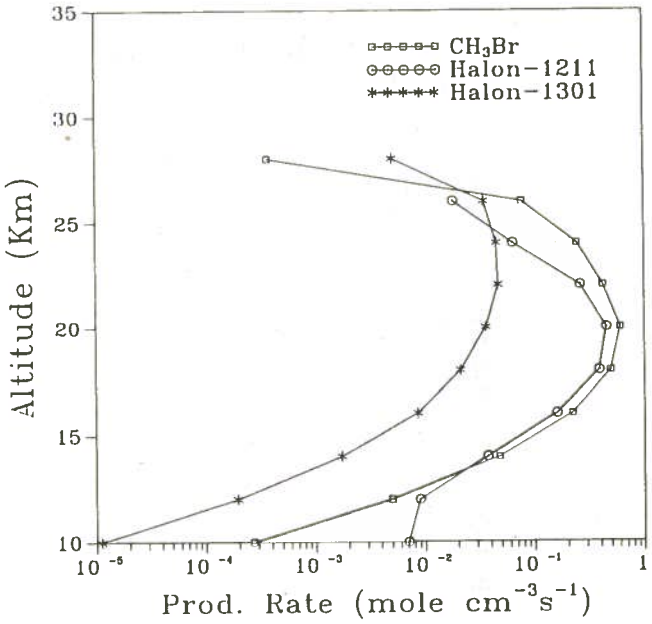
The production rates of bromine radicals from the three main species in the family of bromine



2.3. Typical diurnal variations of NO_x during the period of January 1994 measured at Ahmedabad and at Gadanki, near Tirupati

containing gases, namely CH_3Br, Halon 1301 and Halon 1211 are calculated. These rates have been calculated for a solar zenith angle of 45° using recent solar flux and absorption cross section data. Above 13 km height, CH_3Br is the main source of bromine radicals with maximum production of 33 radicals/cm³/min at 20 km height (Fig. 2.4). Halon 1211 is the second major source of bromine in the 10 to 25 km height. The bromine production from Halon 1301 is dominant only above 25 km. So, eventhough tropospheric concentration of Halon 1301 and Halon 1211 are only 1.7 and 3 pptv respectively compared to the concentration of CH_3Br (8 pptv), their role in the bromine production is significant.

We have now established a laboratory having an ultrasensitive gas chromatograph coupled with a quadrupole mass spectrometer (GC- MS). This



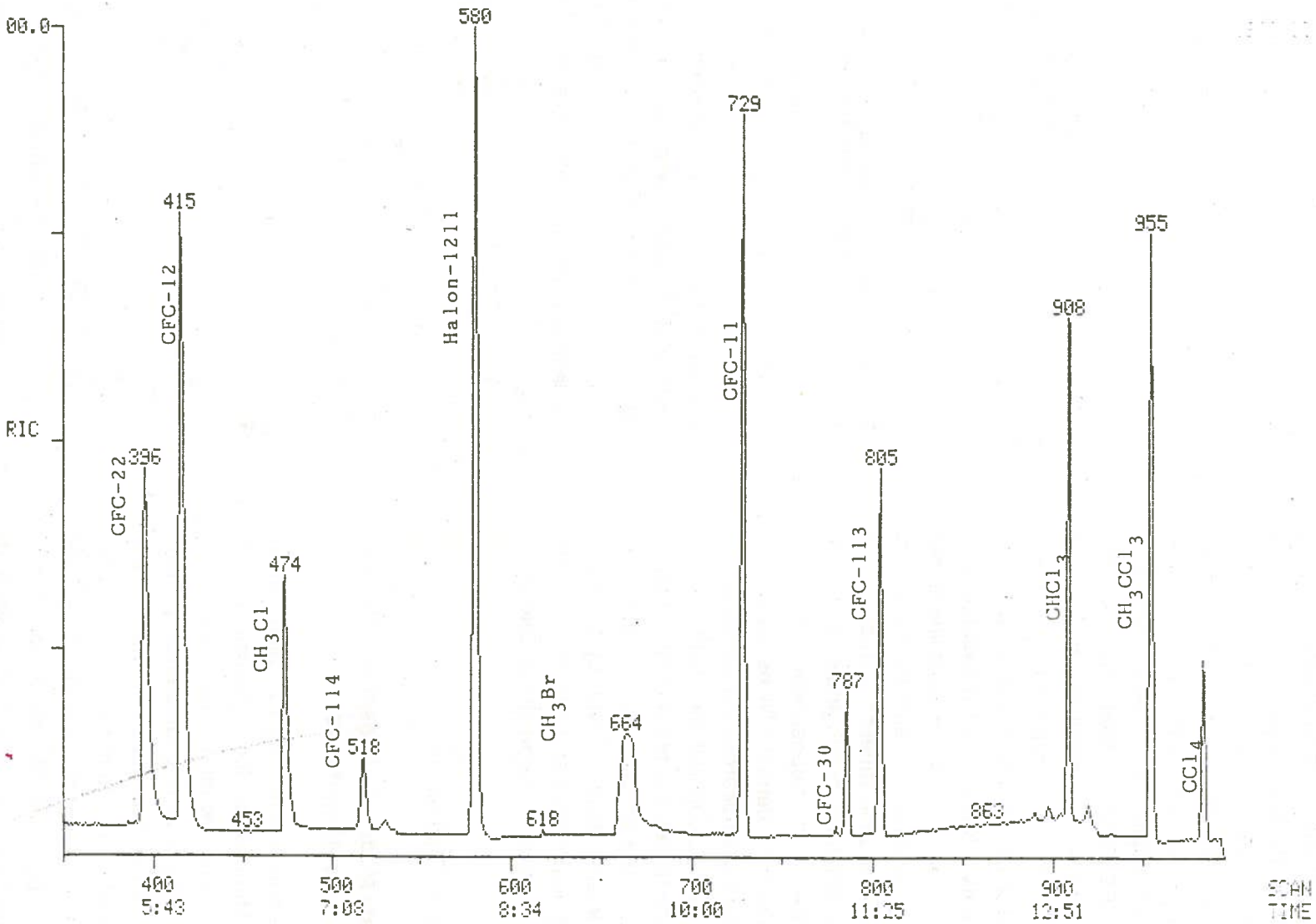
2.4. Calculated production rate of bromine radicals due to photodissociation at different stratospheric altitudes for CH_3Br, Halon-1211 and Halon-1301.

has a capability to analyze almost all of the important gases of interest. This system has been programmed to separate and detect simultaneously 12 halogenated hydrocarbons in a single analysis (Fig. 2.5). A cryosampler has been indigenously developed for collection of air samples at different heights upto 35 km. Balloon flights with cryosampler are planned to study the vertical distribution of various trace gases.

(P.K. Patra, S. Venkatramani, Y.B. Acharya and Shyam Lal)

First measurement of Atmospheric Nitrogen Trioxide (NO_3) at the Polynesian Sector

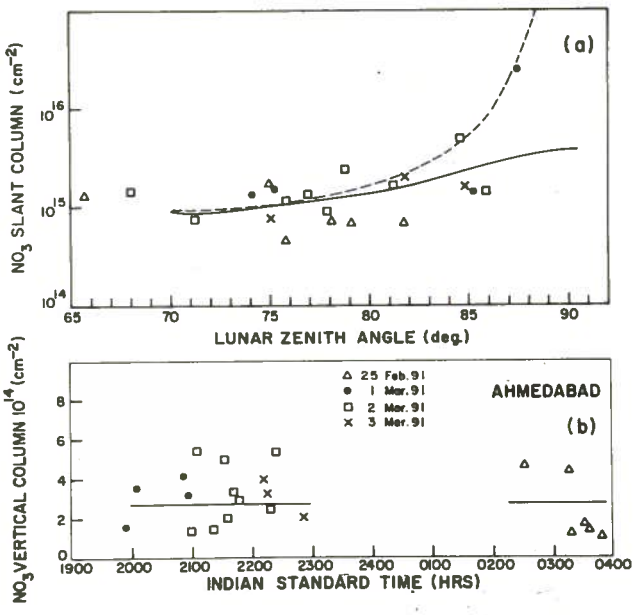
The minor constituents belonging to NO_x, HO_x and ClO_x groups perturb the earth's atmosphere to a significant degree. In the NO_x group, NO, NO_2 and NO_3 are important species. While the variabilities of NO and NO_2 are known to some extent, the features of NO_3 are not properly known,



2.5. Separation and detection of various trace gases using the newly installed GC-MS system.

more so at low latitudes. The strong absorption of NO_3 near 662 nm has been used in a preliminary estimate of the column density of NO_3 using the moon as a source of light. Our setup contained mainly a scanning monochromator, a lock-in amplifier and a photomultiplier tube. The spectrum was scanned from 655 to 667 nm. Measurements were made for three days near the full moon. Fig. 2.6a shows: (a) slant column abundance (upper panel) and (b) vertical column abundance (lower panel) of NO_3 for February - March 1991 measured over Ahmedabad. In the upper panel, solid line shows the variation of stratospheric airmass factor and the dotted line shows the variation of tropospheric airmass factor with lunar zenith angle. Based on the present results, the tropospheric and stratospheric contributions cannot still be estimated. Fig. 2.6b shows that vertical column density of NO_3 remains constant throughout the night. These values are higher by a factor of about 10 compared to the values in the western zone of the same latitude. A detailed study of NO_3 by the same technique with improved instrument performance and by incorporating a diode array detector is planned.

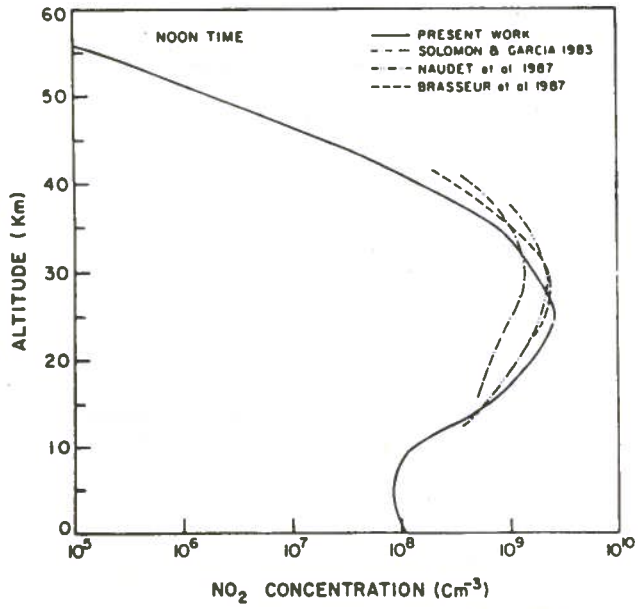
(M. Lal and D. K. Chakrabarty)



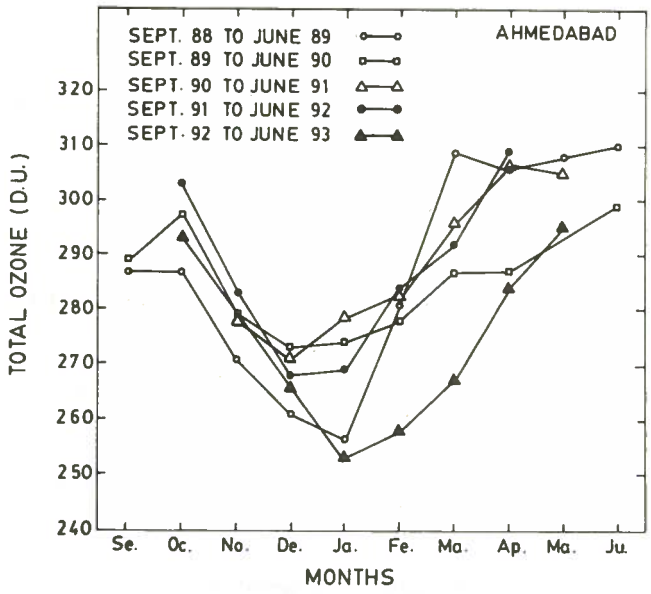
2.6(a). Slant column abundance and (b) vertical column abundance of NO_3 for February and March 1991 over Ahmedabad.

A Steady State Model of Atmospheric Nitrogen Dioxide (NO_2) for Ahmedabad

We have been measuring NO_2 column abundance over Ahmedabad for sometime. It is of interest to examine how far our measured values agree with the theoretical understanding. There are several channels of production and loss of NO_2. NO_2 is produced mainly from the reaction of NO and O_3 and by the photodissociation of NO_3 and N_2O_5 and also by the collisional dissociation of N_2O_5. It is lost by combining with O in two body process and with NO_3 by the three body process in the presence of a third body. Using these reaction channels a 1D steady state model has been prepared. Calculation has been done at 1 km interval with reference atmosphere values of NO, O_3 and T for low latitudes. Fig. 2.7 shows the model profile.



2.7. Theoretical models of daytime NO vertical distribution for low latitude



2.8. Monthly average of total ozone over Ahmedabad before and after Pinatubo volcanic eruption. The plot is from September 1988 to June 1993.

For the sake of comparison three other profiles are also shown. Using this model profile, NO_2 column density of the stratosphere comes out to be 3.0 x 10^{15} cm^{-2}. Our measured averaged column density value of NO_2 during daytime is 2.5 x 10^{15} cm^{-2} validating the chemical scheme adopted for the model.

(M. Lal and D. K. Chakrabarty)

Decrease in Stratospheric Ozone Following the Eruption of Mt. Pinatubo

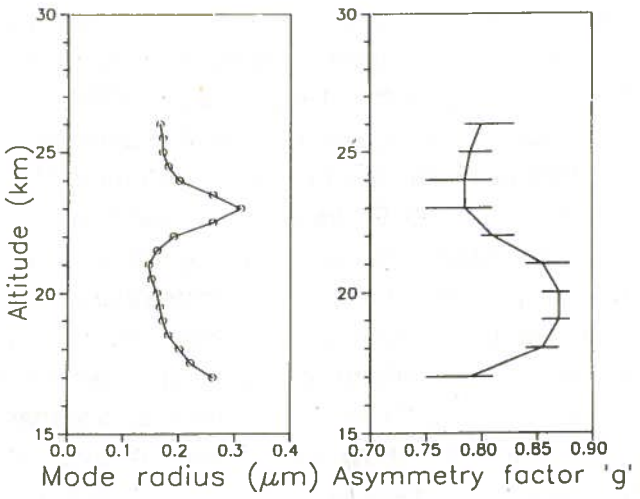
There have been reports of large columnar decrease (26±4 Dobson Units) in ozone over tropics around 16-28 km range after the eruption of Mt. Pinatubo on 15 June 1991 based on measured O_3 by electrochemical concentration cells and UV differential absorption Lidar. A Dobson Spectrophotometer has measured total ozone at PRL during and after Pinatubo eruption. We have examined these ozone data to see any effect of Pinatubo on them. Fig. 2.8 shows a plot of ozone values prior to Pinatubo eruption: from September 1988 to June 1989, September 1989 to June 1990, and September 1990 to June 1991 and after Pinatubo eruption: from September 1991 to June 1992 and September 1992 to June 1993. No spectacular decrease in O_3 has been noticed after Pinatubo eruption. However, after December 1992 upto March 1993 O_3 values are found to have decreased significantly compared to previous years. Incidentally, the Dobson instruments operating at other places in India give different results. A decrease, identical to the one we have observed at Ahmedabad (23°N) has been seen at Varanasi (25°N). At Delhi (28°N), the decrease is observed from September 1992 till the end of 1993. At Poona (18°N), on the other hand, no such decrease was observed.

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

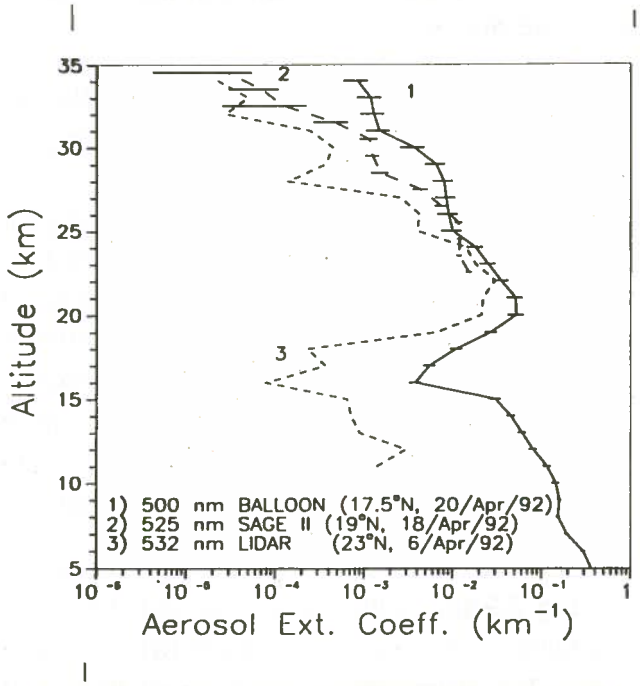
Balloonborne Optical Studies of Mt. Pinatubo Volcanic Aerosols

Using suntracking photometers onboard balloons, the Pinatubo volcanic aerosol layer has been studied over Hyderabad (17.5°N) during October 1991 and April 1992. From the angular distribution of the scattered radiation intensities, the asymmetry factor 'g' defined as the average of the cosine of the scattering angles for the scattered radiation and from the ratio of the aerosol extinction coefficients at 440 and 1050 mm obtained from the direct radiation intensity measurements, the mode radius, r_m of the aerosol size distribution are determined.

Fig. 2.9 shows the altitude variation of 'g' and r_m obtained during October 1991 between 17 and 26 km. The asymmetry factor 'g' varies from 0.79 to 0.87 and the mode radius is found to vary from 0.2 to 0.3 micro metre. The large values of 'g' and r_m indicate the formation of larger aerosol particles due to coagulation in this altitude range.



2.9. Profiles of mode radius and asymmetry parameter of the aerosol scattering function obtained over Hyderabad using balloon-borne photometers, four months after the Mt. Pinatubo volcanic eruption.



2.10. Comparison of the vertical profiles of the aerosol scattering coefficient obtained over the tropics using three different techniques. The observed enhancement in scattering coefficient above 16 km altitude is caused due to the Mt. Pinatubo volcano erupted 10 months prior to the measurements.

Fig. 2.10 shows the comparison of 500 nm aerosol extinction coefficient values in the case of April 1992 flight with the SAGE II (onboard NIMBUS satellite) results at 19°N during the same period with the results of Nd:YAG laser lidar experiment made at Ahmedabad (23°N) two weeks prior to the balloon experiment. A systematic increase in the extinction values is seen above about 24 km with decreasing latitude indicating that the upper edge of the volcanic layer extends to higher altitudes in the equatorial region.

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

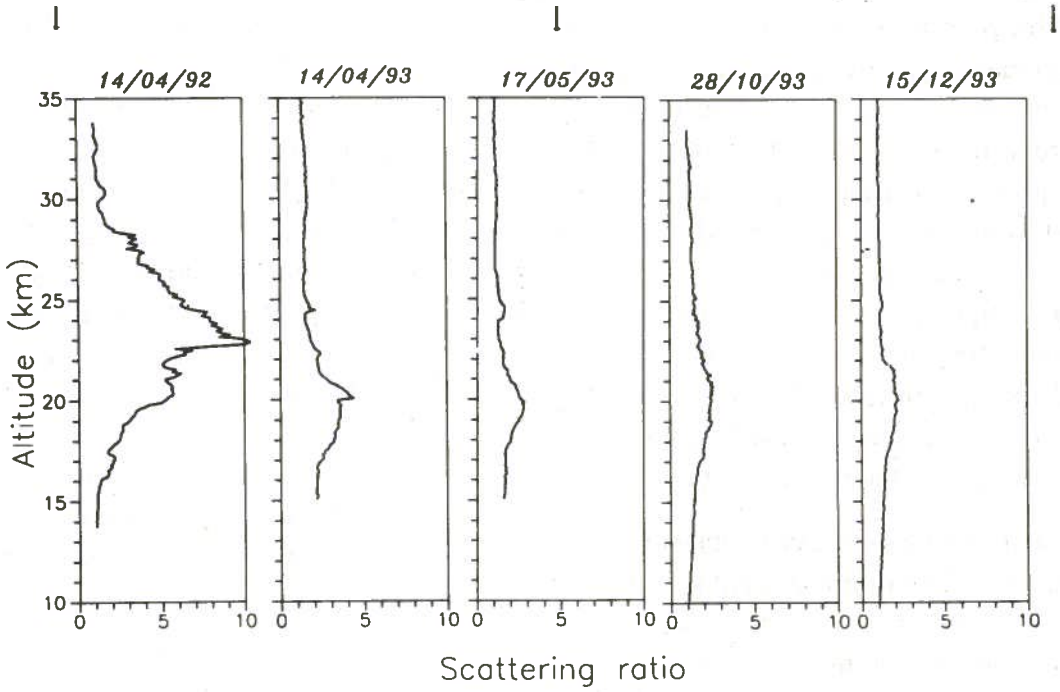
Compact LED Sun-Photometer

A new compact LED sun-photometer has been designed for atmospheric optical depth measurements. LED is used as a spectrally selective photodetector as well as a non-linear feedback element of the operational amplifier. The output voltage which is proportional to the log of the incident solar intensity enables direct measurement of the atmospheric optical depth in selected spectral bands. Measurements of optical depths are made over Ahmedabad. A good agreement within few percent is seen between the optical depths derived using LED as a photo- detector in linear mode and as a photo-detector as well as the feedback element in log mode. The system is an ideal alternative for monitoring of visibility and atmospheric turbidity on any remote location on a continuous basis.

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

Study of Atmospheric Structures using Nd:YAG Lidar

The Nd:YAG laser based lidar laboratory at PRL is fully operational since April 1992. The



2.11. Sample profiles of the scattering ratio (for clean atmosphere scattering ratio is unity) obtained over Ahmedabad using Nd:YAG laser radar. Decay of the stratospheric aerosol layer caused due to Mt. Pinatubo eruption is depicted since April 1992.

system has now been extensively used to study the decay of the stratospheric aerosol layer produced after the Mt. Pinatubo volcanic eruption and molecular air densities up to about 50 km on clear nights. One of the important results is on the volcanic aerosol layer produced at the stratospheric altitudes after the Mt. Pinatubo eruption at Philippines in June 1991. Aerosol backscattering coefficient profiles show varying structural features. An aerosol layer found around 23 km during April 1992 persisted till mid 1992. Later measurements show that the layer has thinned down and its peak has come down to about 19 km (Fig. 2.11). A 1/e folding time of approximately 14 months is estimated for the layer to decay.

Another important study being carried out using the lidar is the measurement of the neutral number density and temperature profiles above about 30 km where the atmospheric aerosol content is negligible. Good agreement is seen between the derived air density profiles and the standard model profiles except on occasions when the profiles show strong wave like perturbations. Attempts are also being made to derive temperature profiles at the stratospheric altitudes and above.

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

Monitoring Aerosol Content over Arabian Sea using INSAT Data

The structure of the radiation field over the Arabian sea plays a crucial role in the regional climatology, and it is witness to a systematic bi-annual wind reversal. Desert aerosol is expected to be transported on a large scale during six

months of the year from the surrounding regions, and a diagnostic study involving the annual variability of aerosol loading is expected to answer questions regarding their role in the radiation budget in the area. Visible pictures from INSAT are being used to monitor atmospheric dust content over cloud free regions of oceans, the corresponding IR data being used to eliminate cloud contaminated pixels. The pixel radiances are interpreted in terms of aerosol optical depths when it is compared with computations of upwelling radiances from a modelled molecular aerosol atmosphere.

A retrieval algorithm to extract relevant aerosol optical parameters (optical depth) has been worked out. From computations of various sun-satellite geometries, a time slot suitable for favourable viewing conditions has been deduced which satisfies the criteria that the detected path radiances for different aerosol models should be minimal. A software has been prepared for yielding contour plots of radiances expected by the VHRR in the region of study for any given date and time. The factors incorporated in the radiative transfer calculations are (i) Optimization of viewing time after determination of scattering angles for various sun-satellite geometries, (ii) accurate parametrization of background reflectance from the ocean, taking into account sea-surface roughness, white caps etc. combined with a vicarious in-flight calibration of the sensors (iii) choice of a suitable aerosol phase function, and (iv) a realistic correction to account for multiple scattering effects.

(Yagnavalkya Bhattacharya, A. Jayaraman and B.H. Subbaraya)

Balloon Flight for Ionisation and Electrodynamics

A balloon flight carrying payloads from PRL and NPL in which the gondola was electrically isolated at 0500 hr was conducted on early hours of 5th January, 1994. With this configuration no gondola charging effect was observed during balloon ascent and data were obtained right from the ground upto the ceiling altitude (35 km). The payloads were conductivity probe, electric field probe, spherical probe, Langmuir probe and a magnetic aspect sensor. The positive ion conductivity and negative ion conductivity were equal till 0700 hr. (Sunrise time 0600 hr. at 35 kms on 5th January 1994). After 0700 hr., the positive ion conductivity started increasing and at 0830 hr. it was more by a factor of five compared to negative ion conductivity confirming our earlier measurements.

After 0830 hr the balloon was brought down by opening an Apex valve, to 22 km in two hours duration. The positive ion conductivity was more than negative ion conductivity upto 26 km during descent and then it became equal to negative ion conductivity. From these measurements and from our earlier measurements in different seasons of the year it is concluded that during daytime, positive ion conductivity is always more than negative ion conductivity above 28 km onwards presumably due to photo electric effect and photodissociation of positive ions to lighter ions by solar UV radiation. Further study is in progress.

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

Refractive Index Irregularities in the Tropsosphere

Signal fluctuations of the VHF radar echoes, at 50 MHz, from troposphere obtained from the Indian MST radar facility at Gadanki near Tirupati were analysed to study the nature of the irregularities in refractive index. The radar was operated in 16 μ s coded pulse mode which gives a height resolution of 150 m. Data were recorded in 129

range bins covering a height range for 3 km to 22 km. Using the vertical beam the radar signals were recorded during 1150-1230 hrs on 8 February 1992.

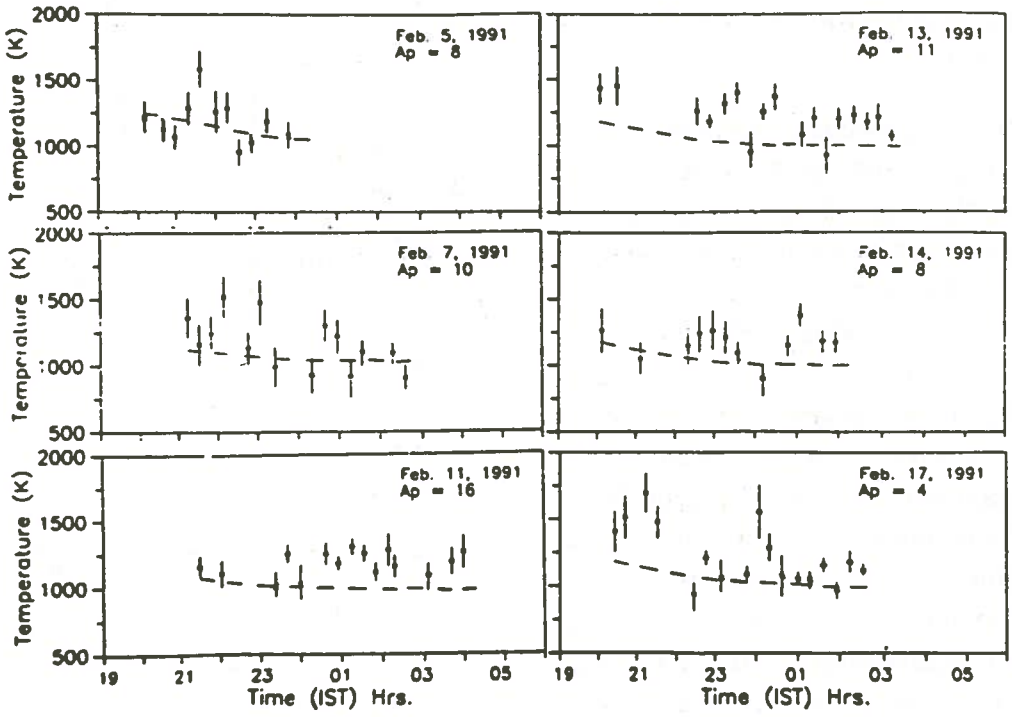
The amplitude probability distributions were compiled for each range bin. Most of the distributions appeared to be of Rayleigh type, however there were some examples showing some specular component also. Another parameter which gives the relative importance of specular and random components of the echoes is the parameter $\overline{R^2} / \overline{R}^2$. The time series data recorded on 8 February 1992 was subjected to this analysis also, showing that this parameter has the values in the range of 1.35 to 1.80 indicating once again that the amplitude distributions are of Rayleigh type. This also indicates that the signals obtained here are mainly due to the backscattering from isotropic irregularities rather than the Fresnel reflection from anisotropic structures. These distributions will be compared with theoretically derived distributions to determine the value of the Rice parameter.

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

UPPER ATMOSPHERE

Variabilities of Thermospheric Temperatures in the Region of the Crests of the Equatorial Ionization Anomaly (EIA)

Significant amount of data has been collected from Mt. Abu (24.6°N; 72.7°E, geographic, 18°N dip lat.) observatory by the central aperture pressure scanning Fabry-Perot Spectrometer covering periods of low to high solar activity conditions. These results reveal that on many occasions the mea-



2.12. The neutral temperatures deduced by spectroscopic means over Mt. Abu, a location in the crest region of EIA, show considerable deviations from the model on many occasions. The geophysical processes peculiar to this region are believed to be responsible for the observed deviations.

sured temperatures deviate considerably from the prediction of the neutral atmospheric model (MSIS-86), bringing out the limitation of the model as applied to the low and equatorial latitudes. The role of the special low latitude geophysical processes that are responsible for the equatorial ionization anomaly (EIA), midnight temperature maximum (MTM), and the equatorial spread-F (ESF), all of which have a say in the thermal structure of the thermosphere were examined. It had been conclusively shown that the joule heating due to the ESF associated irregular electric fields cannot be solely responsible for the enhanced observed temperatures and the more likely candidate had been suggested to be the interaction of the neutral atmosphere with the crests of EIA. (Fig. 2.12).

(S. Gurubaran, R. Sridharan and R. Suhasini)

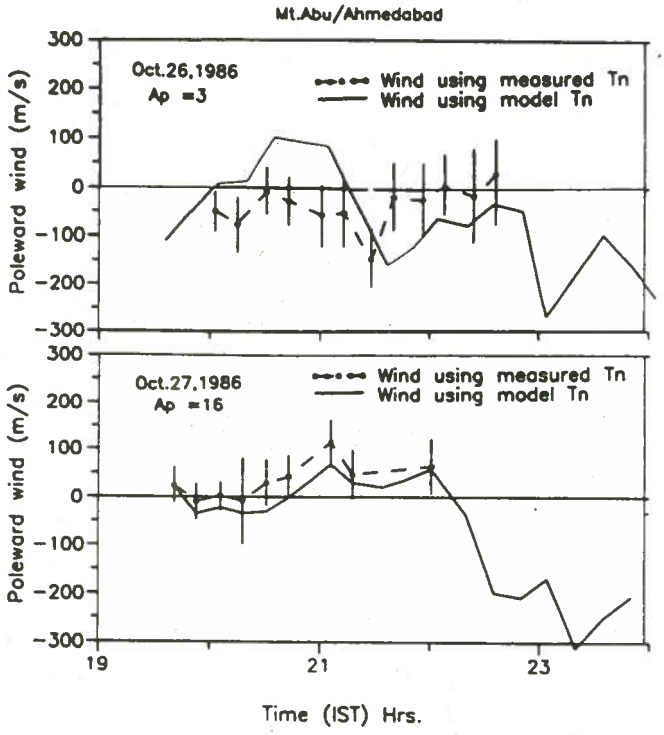
Effects of Neutral Temperatures on the Estimates of Meridional Winds from the Ionospheric Data

Making use of the basic principle that the ionospheric F-region and the thermosphere behave as a closely coupled system, the ground based ionospheric data are used to make the meridional wind estimates. Individual case studies using Mt. Abu and Ahmedabad data on neutral temperatures and F-region parameters have revealed that the large deviations in the neutral temperatures observed on several occasions do have a significant control on the F-region height thus making the meridional wind estimates based on model parameters incorrect. The necessity for the temperature correction, atleast during high solar activity conditions when the deviations from the model are considerably large, has been highlighted. (Fig. 2.13).

(S. Gurubaran, and R. Sridharan)

Rocket Flight from SHAR to Investigate Daytime Equatorial E and F Regions

As a continuation of the Indo-German collaborative programme, daytime F-region studies were carried out by means of a RH-560 rocket from SHAR on 19 April 1993 with several modifications in the payload configuration as compared to the earlier flight conducted in 1987. The German payloads were Resonance cone and plasma potential probes. The Langmuir probes were mounted on booms having half meter length. Three Langmuir probes were used. On one of the booms, one sensor was mounted facing downward while the second sensor pointed upward. On the second



2.13. Estimate of the meridional winds from ionospheric data with and without temperature correction. The estimated winds would grossly differ if the neutral temperature deviations are not accounted for properly.

boom we had used Langmuir probe sensor facing the azimuthal direction. The sweep to Langmuir probe sensor was from - 4 Volt to +4 Volt in 0.5 sec and kept at - 4 Volt for 0.3 second and + 4 Volt for 1 second. This mode can give ion density, electron density and electron temperature.

In all, three resonance cone sensors were used in the above flight, one at the centre of rocket deck and two on booms which were diametrically opposite to Langmuir probe booms. The Resonance probe sensors were operated in transmit/ receive mode alternately (0.2 ms duration). So that both the upstream and downstream resonance cones can be studied near simultaneously. For a short time, the transmitter was kept off to see the background noise. The R.F. signal of frequency 500 KHz was applied with a peak to peak amplitude 0.5 volts. Data were collected in the 70-325 km height region.

Following were the main results obtained from this flight:

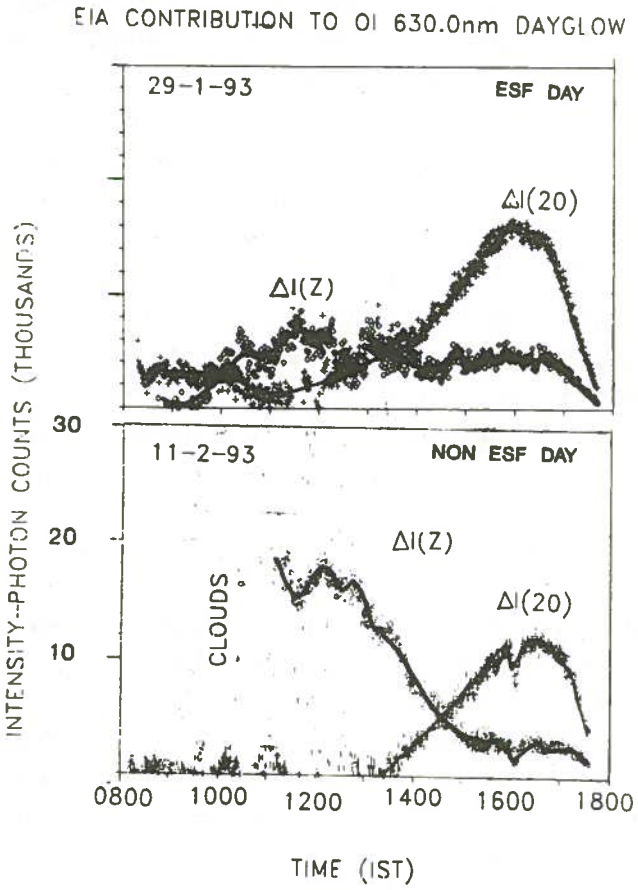
1. The electron temperature measured by Langmuir probe shows a clear maximum at 220 km as predicted by theory. The temperature decreases after 220 km till the apogee.
2. The electron temperature measured by resonance cone also shows well defined maximum at 220 km as shown by the Langmuir probe. However, the electron temperature measured by Resonance cone is less by a factor of about two as compared to the Langmuir probe.
3. The electron density obtained from Langmuir probe data (using constant calibration factor for conversions of current into electron density) does not agree with ionosonde data and so are the results from the Resonance cone probe higher up in F region.
4. The ion density measured by Langmuir probe (converting ion current into ion density using calibration factor from ionosonde at around 100 km) agrees well with ionosonde data of electron density profile upto F region within the experimental uncertainty.

This shows that irrespective of the time of measurements the F- region profiles measured by Langmuir probe by measuring electron current need to be updated and corrected accordingly. This work has been carried out in collaboration with H. Thiemann, Arbiet Weltraum Technik, Germany.

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

Precursor to the Postsunset Equatorial Spread-F(ESF) in OI 630.0 nm Dayglow Intensities

Bidirectional mode of operation of the dayglow photometer, from Waltair (17.7°N; 83.3°E; 10.6°N geomag. lat.) and Ahmedabad (23.0°N; 72.6°E; 17°N geomag. lat) provided the first optical signature of the evolution of the equatorial ionization anomaly (EIA). Having obtained the clue, some of the earlier results from PRL which have indicated a close link between the EIA and ESF, have been put on a firmer footing and precursor to the nighttime ESF has been obtained as early as 1600hr. From the measured 630.0 nm dayglow intensities from zenith as well as 20° elevation pointing north the contribution of excess ionization brought in as a consequence of the development of EIA alone has been estimated (I (Z, 20)) for both zenith and 20° elevation look angles. It has been demonstrated that on a ESF day the peak zenith intensity at noontime was considerably less than the 20° elevation intensities at 1600hr. On a non-ESF day the zenith intensities remain larger than the low elevation intensities (Fig. 2.14); a clear indication for a stronger EIA development to be



2.14. Estimate of the contribution of equatorial ionization anomaly to the OI 630.0 nm dayglow intensities as observed from two different look angles (zenith and an elevation 20° N) from Waltair, on a spread-F and a nonspread-F day. The more the zenith intensities, weaker is the EIA. Therefore, stronger EIA development is conducive for ESF generation.

favourable for ESF to get triggered in the night. These results are the first of their kind providing a precursor to ESF, well before its actual occurrence in ground based ionosondes and radars. This work was carried out in collaboration with R. Raghavarao.

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

Preliminary Results from the RH-560 Rocket Experiments carried out at the Onset of ESF

The successful implementation of a complex coordinated rocket and ground based experiments at the onset of ESF was reported last year. The occurrence of ESF was successfully predicted and the rockets launched providing the background ionospheric and thermospheric conditions at the onset of ESF. Some of the significant results obtained till now;

i) The presence of large scale gradients in the ambient electric field around 180 km which caused the splitting of the ion clouds is reconfirmed at the onset of ESF.

ii) The presence of vertically downward winds of significant amplitudes was recorded providing confirmation to the hypothesis that the neutral dynamical parameters have a significant control in the day-to-day variability of ESF.

iii) Significant amount of neutral metallic atoms (Fe and Mg) forming about 1% of the total densities around 120 km and 0.1% around 140 km has been detected by the Indo-Soviet joint mass spectrometer.

iv) The all sky camera detected the presence of multiple bubbles on this occasion with scale length (zonal separation) of 150-200 km.

v) The Indian MST Radar operated in the ionospheric mode provided the Range Time Intensity maps of the 3 m irregularities. Detailed analysis of the Langmuir probe and ion mass spectrometer data are underway.

(R. Sridharan, R. Narayanan, R. Sekar, N. K. Modi, S. R. Das, S. Gurubaran, D. Pallam Raju, H. S.S. Sinha, H. Chandra, G. D. Vyas, R. N. Misra, M. B. Dadhania, Narain Dutt, G. A. Panchal, H. D. Parikh and V. K. Parmar).

Equatorial Spread-F Study using Rocket-borne Langmuir Probe and Ground Based VHF Scintillations

An experiment was conducted in September-October 1988 to study the well developed equatorial spread-F using rocket borne Langmuir probe, two pairs of double probes, ground based VHF scintillations at 136.1 MHz and a digital ionosonde. The rocket flight was conducted on 4 October 1988 at 2130 hrs from SHAR (14°N, 80°E; 6.5°N dip lat). The scintillations and ionosonde data were examined for the period 15 September - 5 October 1988. A part of the detailed analysis was completed during this year and the results of the same are presented below.

(i) The occurrence of scintillations and spread-F during the campaign was very high with maximum hourly percentage occurrence of about 70 and 80 percent, respectively.

(ii) Generally the onset of spread-F occurred slightly before 1900 hr with the appearance of strong amplitude scintillations. This was soon followed by range spreading.

(iii) On days with no spread-F, the F-layer base rose to 300-320 km but on days when spread-F was present the layer base rose to heights as large as 400 km.

(iv) The electric field reversal as inferred from the h'f variations (from the ionosonde), occurred around 1930 hr on spread-F days and around 1900 hr on days without spread-F.

(v) The ionograms, taken at 5 minute intervals on several nights, were used to determine vertical drift velocities and these exceeded 50 m/s on spread-F days in the post-sunset period.

(vi) At the time of rocket launch, strong blanketing type of E_s with several multiple echoes appeared around 105 km. The electron density profile obtained from the Langmuir probe data also showed an extremely sharp layer at 105 km and another at 130 km.

(vii) The irregularities associated with spread-F were seen at different altitudes, the prominent being between 210 and 250 km and between 300 and 320 km. The power spectra of the irregularities have been obtained both from the in-situ and scintillations data.

The spectra of irregularities from the in-situ measurements was compiled for the scalesize range of 20m - 200m; the spectral index varied between - 2.0 to - 4.5 with a mean values of - 3.4. The spectral index from the scintillations data around the flight time is - 3.8; this will correspond to spatial one dimensional spectral index of - 2.8. This work was carried out in collaboration with Satyaprakash.

(H. Chandra, G.D. Vyas, H.S.S. Sinha, and R.N. Misra)

Optical Imaging of Plasma Depletions Using 630 nm and 777.4 nm Nightglow

Large scale ionization irregularities (horizontal wavelengths ranging between few tens of km and thousands of km) in the F- region wherein the plasma density is very much depleted as compared to the background are termed as plasma depletions, bubbles or holes. Occurrence of plasma depletions on one night and not on the other, presence of intense 3-meter irregularities whenever these bubbles are present and their large vertical and horizontal velocities are some of the features which

have intrigued the ionospheric physicists for quite some time.

A ground based all sky optical imaging experiment for plasma depletion study was developed at PRL which makes use of 630 nm and 777.4 nm nightglow emissions, that are produced by dissociative recombination of O_2^+ with electrons and radiative recombination of O^+ and electrons, respectively. Major contributions to 630 nm and 777.4 nm emission comes from the electron density layers which are centered around 250 km and F_2 peak, respectively and hence these lines can be used to map the plasma depletions when they are located at these altitude regions.

The optical imaging system uses a fish eye lens to cover a large field of view (180°), a field lens to converge the diverging photon beam after the fish eye lens, a collimator to ensure a parallel beam, 10 A interference filters to select the emission line, an imaging lens, a high gain image intensifier to get a bright image and a 35 mm camera to photograph this image. With this instrument one can take a snapshot of plasma density over the entire field of view with exposures ranging between 15 sec to 2 min, depending upon the intensity of emission.

A campaign of optical imaging experiment was conducted from SHAR, India (13°41'N, 80°E; 6.5°N dip lat) during 14-21 February 1993. Out of the eight nights observations, plasma depletions were observed only on three nights, although spread-F was present on five nights. These depletions started developing around 1930 hrs but around that time they were usually very weak. By about 2100 hrs they attain prominence and can be seen upto about midnight. Depletions are first seen in 630 nm i.e. when they are located around 250 km. Fig. 2.15 shows a well developed depletion along N-S in the central part of the picture and a weak developing depletion on the western side. Fig. 2.16 shows the same depletions when they have reached the F_2 peak region.

An important feature of these depletions is that the region of depleted density is surrounded by region of enhanced density on the eastern as well as the western edge i.e. in the immediate neighbourhood of the depletion density is much more (by a factor of 2-3) than the background density.

The orientation of depletions is at times parallel to the geomagnetic field lines but occasionally it makes an angle upto about 15° to the west. The E-W and N-S extents of these depletions were found to be in the ranges of 70-100 km and 1000- 2000 km, respectively.

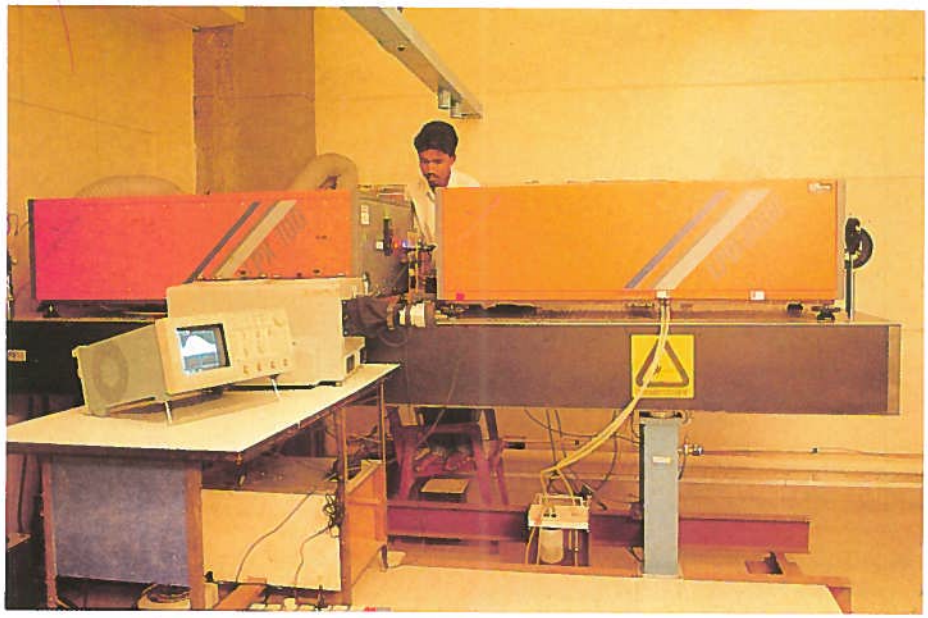
Eastward velocity of these depletions, which is determined by tracking a particular depletion through a number of frames, is found to be in the range of 50-190 m/s.

Fig. 2.17 shows a surface plot of the plasma density distribution as seen in 630 nm line (i.e. around 250 km). One can clearly see the plasma depletions, specially the slope of the walls of the depletions.

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

VHF Scintillations Associated with Daytime Spread-F

Nighttime equatorial F-region is characterised by the presence of structured plasma covering a vast range of scale sizes. These are responsible for the phenomena of spread-F as seen in iono-

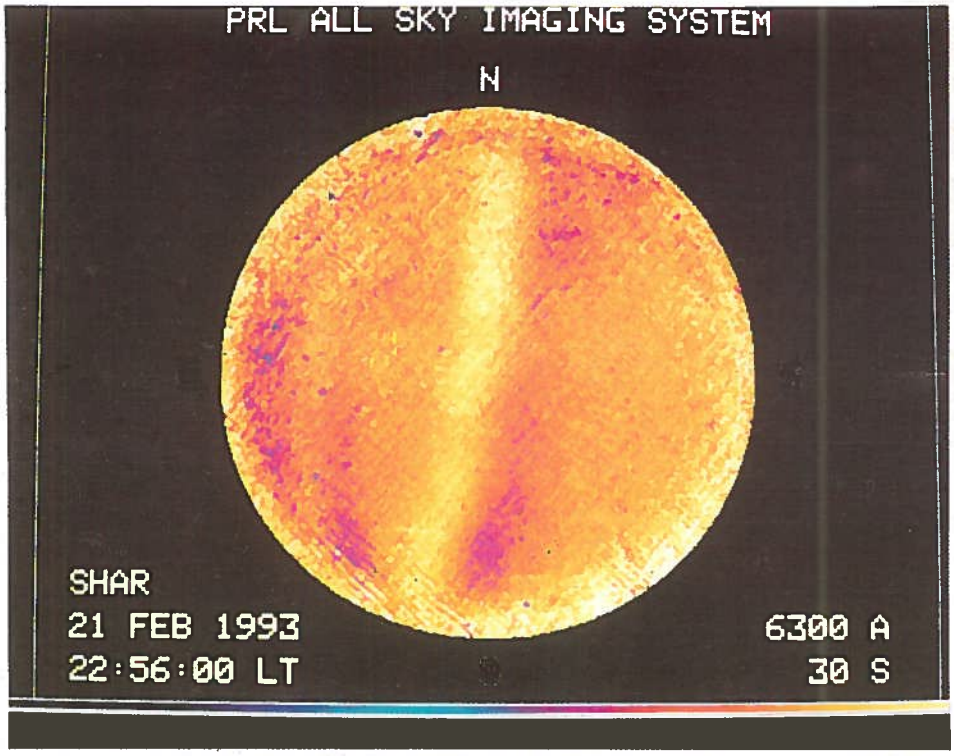


Excimer and Dye Laser for the study of processes of atmospheric importance.

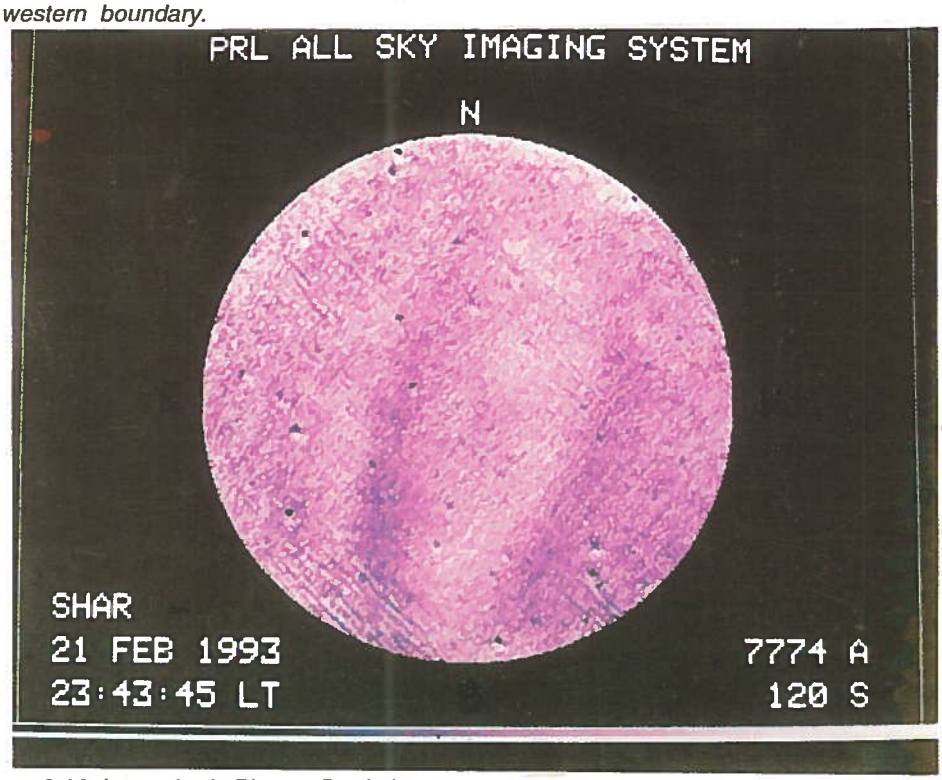
The Nd - YAG Lidar system at PRL for studies of atmospheric aerosols.

Photograph showing the GC-MS system together with the cryogenic air sampler. The sampler will be launched on a balloon to collect air samples at different heights.

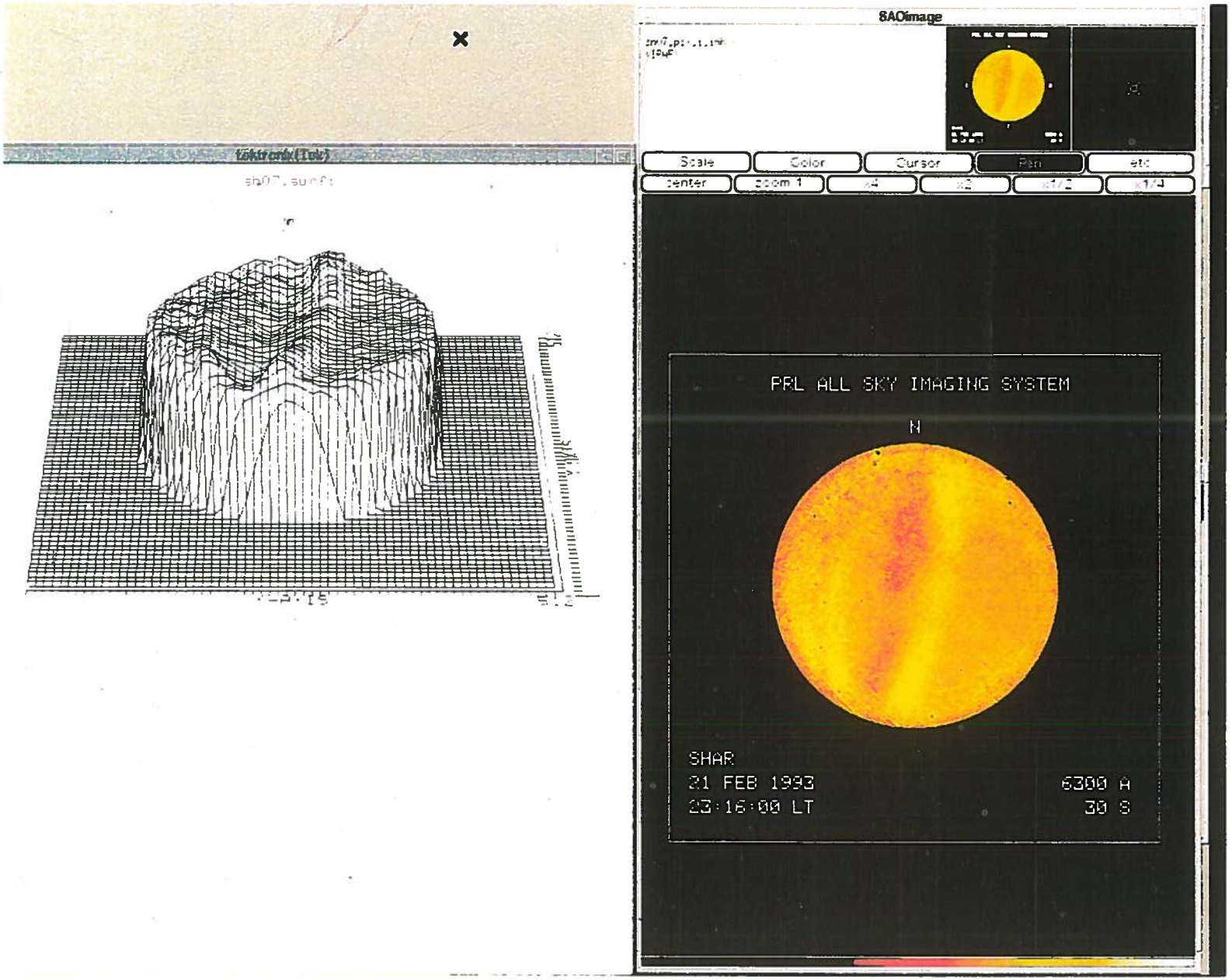
Intercomparison of different balloon - borne experiments to measure electrical parameters in the stratosphere.



2.15. Ionospheric Plasma Depletions as seen in the 630 nm image taken by PRL's All Sky Optical Imager. A central band aligned in N-S represents a well developed plasma depletion overhead. A second plasma depletion which is developing can be seen near the western boundary.



2.16. Ionospheric Plasma Depletion as seen in the 777.4 nm image taken by PRL's All Sky Optical Imager.



2.17. 3 D View of Plasma Depletions observed at Shar on 21 February 1993 at 2316 hrs. by Allsky Optical Imaging System. (For viewing convenience regions of plasma depletions are shown as crests and enhancements as troughs and the picture is slightly tilted in the horizontal plane).

spheric soundings and the scintillations of radio waves traversing through the ionosphere. On occasions, there are strong daytime scintillations associated with blanketing type of sporadic E. From the network of VHF scintillation receiver stations in India detailed studies on the occurrence characteristics have been made. Power spectral features of the scintillations have also been studied both in the equatorial and near the anomaly crest latitude. Only study of the power spectra of daytime scintillations in India has been done for scintillations over Ootacamund associated with E-region.

An event of strong daytime scintillations associated with F- region was recorded over Bombay on 12 November 1991. The scintillations appeared in three distinct patches of short duration during the night of 11-12 November 1991 between 2000- 2040 hr, 2130-2354 hr and 0222-0242 hr followed by a long patch between 0453-1312 hr. Scintillations were not observed over Ahmedabad situated about 500 km north. However, strong scintillations were observed over Trivandrum both during night time and daytime (0624-1027 hr). The ionosphereic data over Ahmedabad and Kodaikanal near magnetic equator show an unusual and large rise of the F-layer around 0300 hr which amounts to a vertical upward drift of about 50 m/s. The geomagnetic data at Trivandrum and Alibag show a sudden commencement at 2248 hr on 11 November 1991. The night time scintillations were associated with the postsunset rise of F-layer at Kodaikanal (no height rise over Ahmedabad) with the irregularities generated in the equatorial region and extending to latitudes upto at least the anomaly crest region along the field lines. However, the patch observed during daytime appears to be associated with the height rise seen both at Ahmedabad and Kodaikanal. The earlier occurrence over Bombay indicates that the irregularities generated were local. The equal magnitude of the vertical drift at the two locations suggests that the rise was caused by the electric fields of high latitude origin associated with the sudden commencement, which penetrated to low latitudes.

The scintillation index S_4 computed from the digital data recorded over Bombay showed fluctuations between 0.1 and 0.7 with a periodicity of about half an hour. The power spectra have been studied for the first time for daytime F-region scintillations at low latitudes. The spectral index values range between 1.5 to 5.0 with a mean value of 2.8 which is similar to the value obtained for the nighttime scintillations over Ahmedabad.

This work is done in collaboration with the Indian Institute of Geomagnetism, Colaba, Bombay.

(H. Chandra and G.D. Vyas)

Non-linear Numerical Simulation of ESF

The non-linear simulation model developed in PRL has been put to use to estimate the significance of the seeding perturbation amplitude in the day to day variability of ESF. The estimate of the minimum amplitude of the perturbation required to trigger ESF in a realistic time frame under realistic thermospheric and F- region conditions reveal that a perturbation amplitude of even 0.5% of the background plasma density would suffice for the evolution of a bubble. Since such perturbations could easily be generated during sunset conditions, it is concluded that the seeding agency might not be playing an important role in the day to day variability of ESF.

In another exercise, a case study on the evolution of equatorial spread-F (ESF) was carried

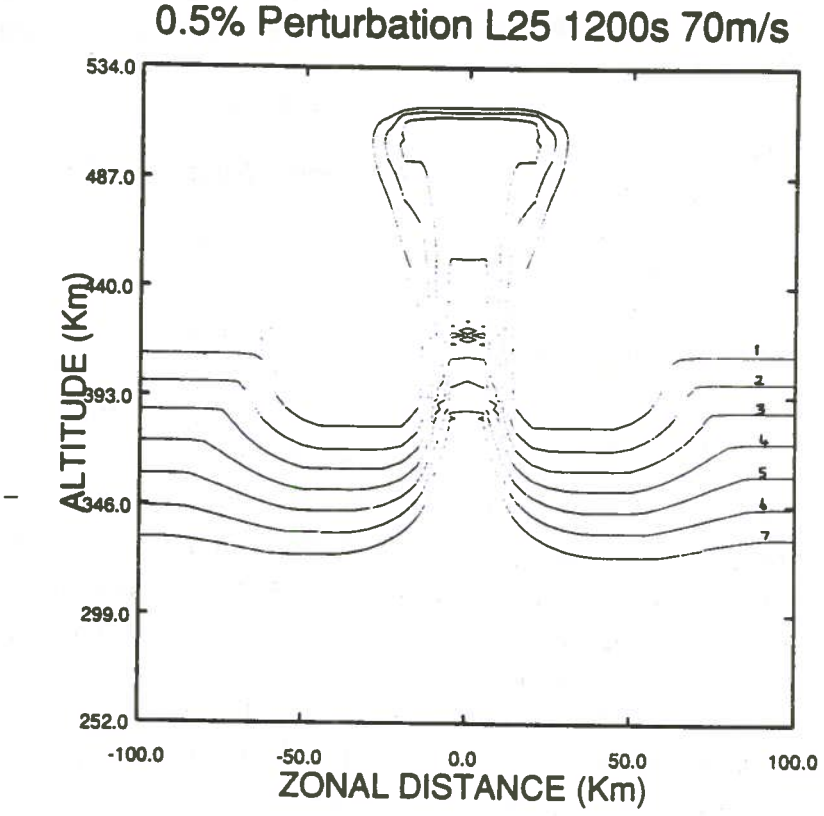
out using the nonlinear simulation model and the coordinated measurements of electron density, electric field, neutral winds and the spatial (zonal) map of electron densities at the onset time of ESF, available in the literature. The development of irregularities using our model is compared with the observation. The investigation reveals that the nonlinear contributions of other agencies apart from gravity are absolutely necessary to explain the observation, in a slowly evolving ESF event, even when large (5%) amplitude of initial perturbation is present. This results confirm our earlier hypothesis ie. the other agencies like electric field, vertical and zonal winds play a crucial role in determining the day-to-day variability of ESF. (Fig. 2.18). This work was done in collaboration with R. Raghavarao.

(R. Sekar and R. Suhasini)

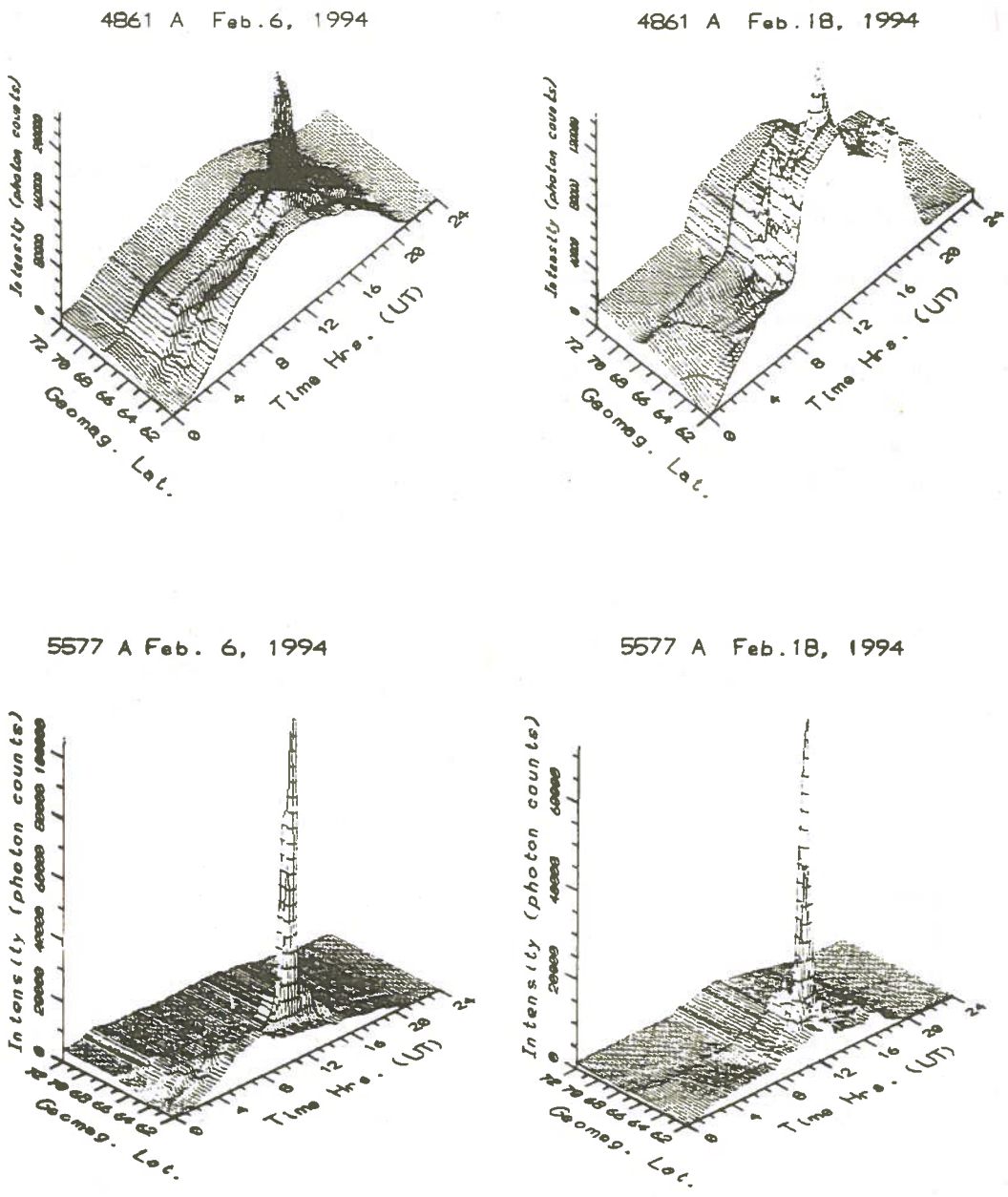
Optical Aeronomy from Antarctica

A new multiwavelength dayglow photometer has been developed incorporating several novel features both in optics and also in the data acquisition system (see title page). Simultaneous observation of three wavelengths at different elevation angles has become possible with these technical developments.

This unique instrument has been installed and successfully commissioned *Maitri* the permanent



2.18 The development of plasma bubble above F-region peak densiy altitude (450 km in this case) with an initial perturbation amplitude of only 0.5% of the ambient plasma density. 1,2,3,4,5,6 and 7 represent the isoelectron density contours ranging from $10^{5.5}$ cm^{-3} to 10^{4} in steps of $10^{0.25}$.



2.19. First results on the daytime auroral emissions excited by low/high energy electrons and protons. The spatial and temporal variabilities of different emissions are depicted round the clock.

Indian station at Antarctica. The firstever *daytime optical auroral* emission measurements have been made (Fig. 2.19). Auroral emission intensities excited by incoming low and high energy electrons and protons have been monitored and from their variabilities, the relative importance of the various exciting mechanisms at different occasions have been studied. Indications for the signatures from the polar cusp region have been obtained and processes associated with the solar wind magneto-

sphere - ionosphere interactions are being investigated.

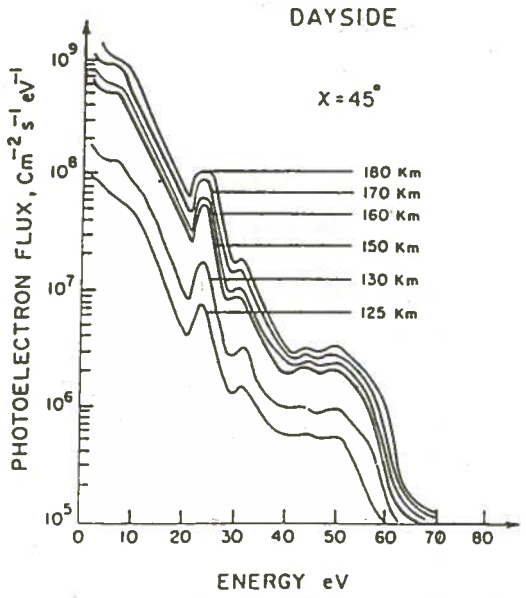
(R. Sridharan, D.P. Raju, R. Narayanan, N. K. Modi and B. H. Subbaraya).

PLANETARY/COMETARY ATMOSPHERES

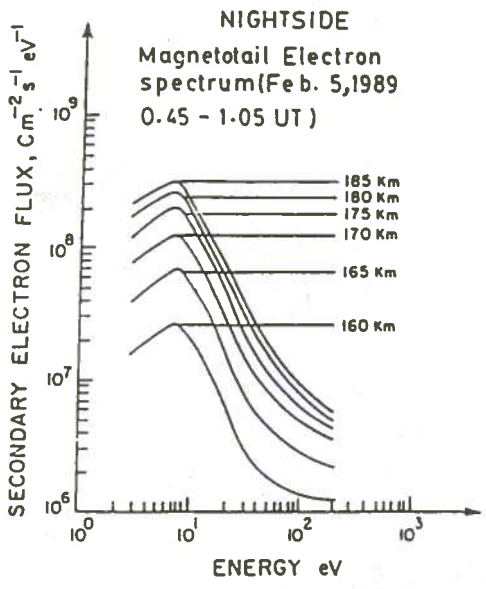
Photoelectron and Secondary Electron Fluxes in the Ionosphere of Mars

During in situ measurements onboard Phobos-2 Martian orbiter, the electron fluxes were measured on February 5, 1989 in the magnetotail by Hyperbolic Electrostatic Analyzer (HARP) experiment within the energy range 3-480 eV. Mars has a hybrid magnetosphere which is composed of the captured interplanetary and intrinsic magnetic field. In analogy to Earth's atmosphere, we have assumed that the magnetotail electrons precipitate down in the nighttime along the magnetic field lines and reach at the top of the Martian atmosphere. These electrons collide with the atmospheric constituents and produce the secondary electrons at different altitudes. Due to the lack of observational information about the magnetically connected regions, we have assumed that local magnetic field inclination at Mars is 90 degree.

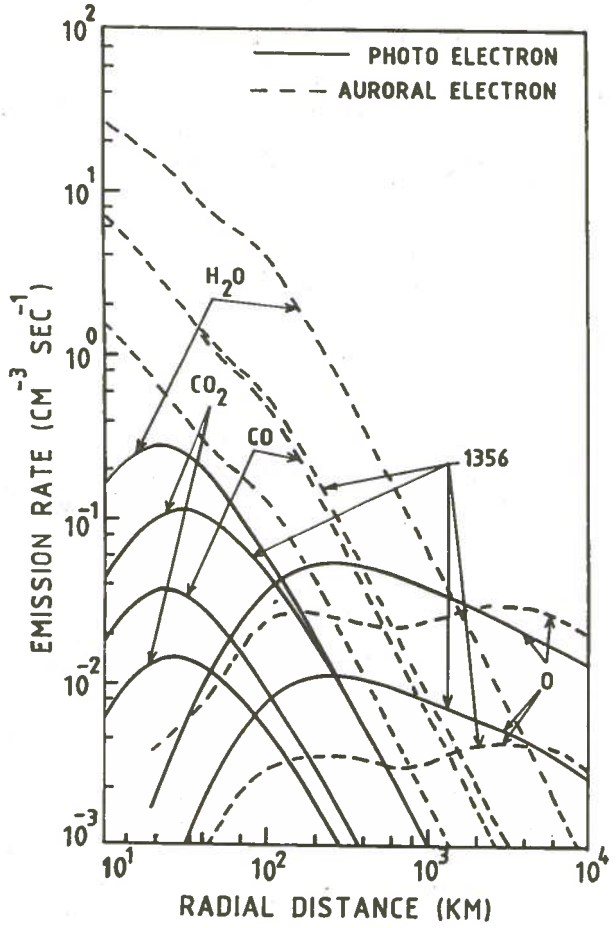
The electromagnetic radiation also penetrates the Martian atmosphere and is absorbed producing the photoelectrons. These photoelectrons and secondary electrons give a very important clue about the mechanisms of daytime and nighttime ionospheres of Mars respectively. A comparative study of these two fluxes at different altitudes are shown in figure 2.20a,b. The peak of secondary electron fluxes fall within a few eV range. The photoelectron fluxes are more structured due to the absorption of the different lines present in the solar spectrum.



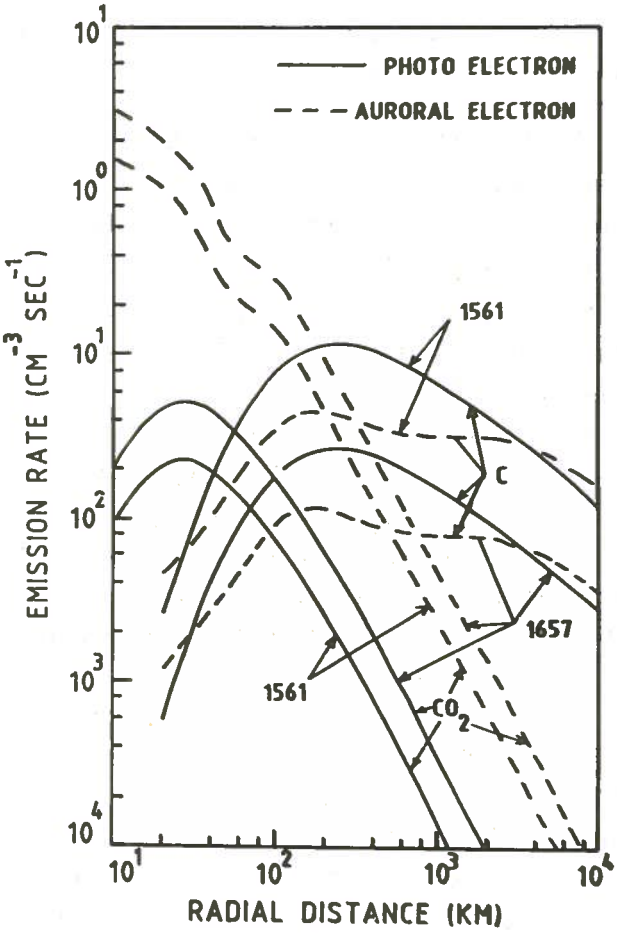
2.20a. Photoelectron fluxes at selected altitudes for 45° solar zenith angle in the ionosphere of Mars.



2.20b. Secondary electron fluxes at selected altitudes.



2.21a. Emission profiles of OI 1304A and 1356A(left) for photoelectron and auroral electron impact excitation of H_2O, CO, CO_2, and O in the inner coma of Comet Halley. Profiles of 1356A are depicted by arrowed line while the other profiles correspond to 1304A. Profiles are marked by the target species.



2.21b. Emission rate profiles of CI 1657A and 1561A (right) for photoelectron and auroral electron impact excitation of CO_2 and C in the inner coma of Comet Halley. Profiles are marked by the target species.

Moreover, the photoelectron fluxes are higher by about an order of magnitude and loose their energy at low altitudes than the secondary electron fluxes. The prominent spectral features of the photoelectron flux in the energy range 20-30 eV are due to the absorption of strong He-II Lyman alpha lines at 304 A.

(S.A. Haider)

Production and Emission of Atomic Carbon and Oxygen in the Inner Coma of Comet Halley

The brightness of carbon (CI 1657 A, 1561 A) and oxygen (OI 1304 A, 1356 A) emissions on comet Halley have been measured by International Ultraviolet Explorer, Far Ultraviolet Spectrograph onboard a sounding rocket and Pioneer Venus Orbiter Ultraviolet Spectrometer experiments. The presence of these emissions posed a puzzle since it could not be explained by photon-impact ionization of the observed amount of CO, CO_2 and CH_4. Neutral carbon and oxygen are not the parent species of comet Halley. Several authors have tried to explain these observations by making different theoretical models. All studies indicate that

additional sources of atomic carbon and oxygen are required to explain the observations.

We have studied the various processes of the production and loss of neutral atomic carbon and oxygen in the coma of comet Halley. Subsequently, the generation of OI, 1304 A, 1356 A and CI 1561 A, 1657 A emissions are studied. The main objective had been to the role of high energy auroral electron in different physical and chemical processes in the cometary coma and thereby affecting the production, of carbon and oxygen and their emissions. Ion- neutral, neutral-neutral and electron-ion chemistry are included in this study so as to investigate the possible formation and loss of carbon and oxygen through chemical reactions.

In figure 2.21a, the emission profiles of OI 1304 A calculated for photoelectron and auroral electron impact on H_2O, CO_2, CO and O are presented. As expected, the auroral electron impact dissociative excitation of H_2O dominates but beyond 2000 Km direct excitation of O by electron impact is the main process of OI emission. In the same figure, we have also shown the emission profiles of OI 1356 A for photoelectron and auroral electron impact on O and CO_2. The calculations of CI 1657 A and 1561 A emission profiles for photoelectron and auroral electron impact on C and CO_2 are shown in figure 2.21b. The total intensity of these lines are obtained by integrating the emission rates. The above results are compared with the other theoretical calculations and the estimated values obtained from observations.

(S.A. Haider)

List of papers published during 1993-94

1. Gurubaran, S. and Sridharan R, "Effects of meridional winds and neutral temperatures on the F-layer heights over low latitudes", J. Geophys. Res., **98**, 11629 (1993).

2. Haider, S. A., Comparative study of electron fluxes, ionization rates, ion and electron densities due to photoelectron and magnetospheric electron interaction with the atmosphere of Mars, Current Science, **66**, 577 (1994).

3. Jayaraman, A. and Subbaraya, B.H., "Monitoring of aerosol content over ocean surfaces using INSAT data" in Advances in Tropical Meteorology", R.N. Keshava Murthy and P.C. Joshi (Eds.), pp. 356-365, Tata McGraw Publ. (1993).

4. Jayaraman, A. and Subbaraya, B.H., "In-situ measurements of aerosol extinction profiles and their spectral dependencies at tropospheric levels", Tellus, **45B**, 473 (1993).

5. Jayaraman, A., "Role of Middle Atmospheric coupling processes in Ozone Change", Current Science, **64**, 666 (1993).

6. Lal, M., Sidhu J. S., Das, S. R., and Chakrabarty, D. K., "Atmospheric NO_3 observations over low latitude northern hemisphere during night, J. Geophys. Res., **98**, 23029 (1993).

7. Sekar R., Suhasini R., and Raghavarao R., "Effects of Vertical Winds and Electric Fields in the Nonlinear Evolution of Equatorial Spread-F", J. Geophys Res., **99**, 2214 (1994).

8. Sridharan, R., Narayanan, R., Modi, N. K. and Pallam Raju D., "A novel mask design for multiwavelength dayglow photometery", Appl. Optics, **32**, 4178 (1993).

9. Sridharan, R., Sekar, R., and Gurubaran S., "Two dimensional high resolution imaging of the retrieval of the equatorial fountain, "J. Atmos.Terr. Phys., **55**, 1661 (1993).

The Earth Sciences and Solar System Division was reorganised this year into two scientific areas, the *Oceanography and Climate Studies* and the *Solar System and Geochronology.* The Oceanography and Climate Studies 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 time scales and chemical and isotopic 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 address 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.

OCEANOGRAPHY AND CLIMATE STUDIES

Following the reorganisation of the Division, the research activities of the Oceanography and Climate Studies area focussed on (i) Oceanographic Studies, (ii) Palaeoclimate and Environmental Programmes, and (iii) Hydrology. In addition, efforts to model isotope systematics in multicomponent systems and water movement in sub-surface aquifers were also made. In the report that follows the highlights and summary of progress are described.

A mathematical formulation relating to Rayleigh fractionation of isotopes was developed to characterise the isotopic composition of minerals that are continuously formed and removed from a multicomponent reservoir with each component having its characteristic isotopic signature. This formulation will provide a better understanding of the sources contributing to the stable isotopic signature of minerals in mantle derived rocks. This information, in turn, could be related to temperature, pressure, and melting conditions during their formation.

Carbon and oxygen isotopes in pedogenic carbonates (i.e. carbonate precipitates/nodules in soils) can provide information on the partial pressure of atmospheric CO_2 at the time of their formation. The Lameta beds of Central India provide an ideal set of carbonates to obtain information of CO_2 levels during the Cretaceous (~ 70 Ma). The carbon and oxygen isotope studies of these samples suggest a dominance of C_3 type vegetation, enriched by ~ 3 ‰ in $\delta^{13}C$ compared to contemporary C_3 vegetation. The $\delta^{13}C$ enrichment requires that pCO_2 levels during the late Cretaceous atmosphere were in the range of (1000 - 2000) ppmV compared to the present day value of ~ 300 ppmV. The oxygen isotopic ratios of these samples on the other hand, suggest an increase in continental effect in precipitation due to the then larger size of the Indian sub-continent.

Another topic of current interest relating to pedogenic carbonates is their role in regulating atmospheric CO_2 levels. To assess the significance of these deposits in influencing past atmospheric CO_2 levels, it is necessary to know their growth history. However, the determination of chronology of these deposits based on conventional radiometric dating methods has not been very successful because of their open system behaviour. We have developed a new dating method for these "dirty" carbonates deposited during the past few hundred thousand years based on luminescence dosimetric analysis of minerals contained in them. Studies on the abundance of these carbonates as a function of age

and their isotopic systematics should open new possibilities in Quaternary Palaeoclimatology.

Besides these important new results, the area has also made significant contributions through identification of three phases of glacial advances on the Himalaya, documentation of changes in sea level in the Saurashtra coast during the past few thousand years. In oceanography, studies on the dynamics of water circulation in the Arabian Sea and the Bay of Bengal using radiocarbon and stable isotope tracers were initiated. In addition, the area actively participated in the national JGOFS programme to study air-sea exchange of trace gases and to determine time-scales of particle dynamics in the water column using U-Th series nuclides.

In an important application of tracer techniques scientists from our area tried to identify the source of recent bacterial and fungal contamination in the water supply to Ahmedabad from the French wells located in the Sabarmati river bed. The diffusion model based on chemical tracer and pumping test data established that the contamination took place from the advancing pollution front caused by years of sewage discharge into the river bed. This important study suggested recommendations which will isolate the sewage discharge points and hopefully eliminate the bacterial contamination in future water supply.

Oceanographic Studies

In the field of oceanography, our studies focussed on coastal and deep water circulation in the Arabian Sea, air-sea exchange of trace gases across the Arabian Sea and particle dynamics using U-Th series nuclides. Studies on air-sea exchange and particle dynamics are a part of the national JGOFS programme, whereas the circulation studies were initiated last year.

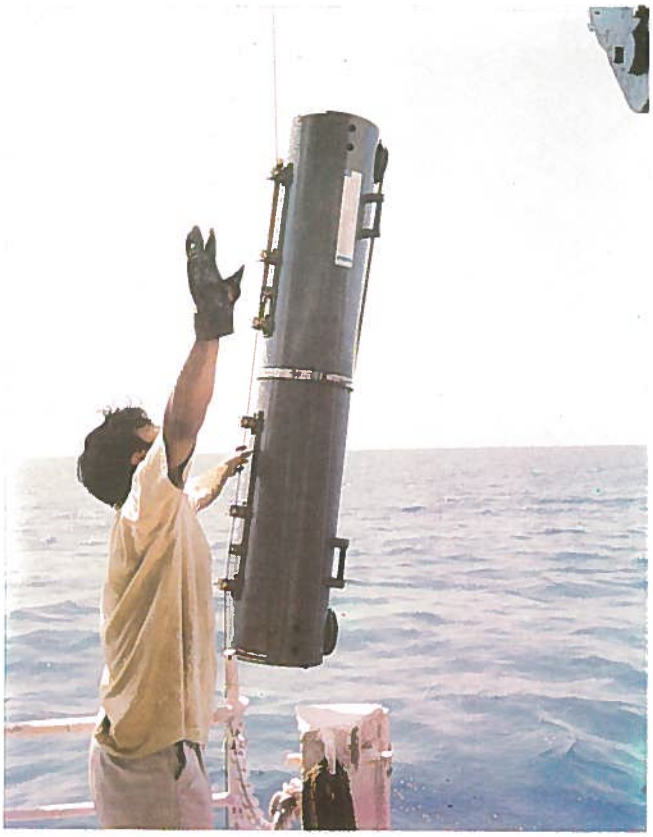
Air-Sea Exchange of Gases Across the Arabian Sea

Seasonal reversal of wind system and definite patterns of rainfall characterise the summer and winter monsoons of India and south east Asia. The monsoon, particularly the south west monsoon, causes extensive upwelling and facilitates air-sea exchange of trace gases. One of our current programmes is to determine the air-sea exchange rate of CO_2 and other trace gases in the Arabian Sea and to evaluate the role of this oceanic region in the overall budget of the carbon cycle. We approach the problem in two ways.

First approach is through the study of carbon isotope systematics of atmospheric CO_2 and its variation. The monsoon systems and associated oceanic exchange of CO_2 is expected to influence the isotopic composition of CO_2. Therefore, a seasonal study of $\delta^{13}C$ in atmospheric CO_2 in and around the Arabian Sea should provide information on the air-sea exchange of CO_2.

The Arabian Sea is sufficiently large to exert measurable influence on the atmospheric trace gas composition and small enough to respond quickly to the seasonal changes in the wind system associated with the summer and winter monsoons. To determine the role of the two monsoons on the atmospheric CO_2 content and its $\delta^{13}C$ it is essential to identify a sampling station which is far away from urban influences but close enough to the coast to respond to the changes brought about by air-sea exchange of CO_2. The efforts of the last two years have identified such a station - Cape Rama about 100 km south of Panaji, Goa on the west coast of India.

Seasonal variations in the atmospheric CO_2 and its carbon isotopic ratio in the Cape Rama



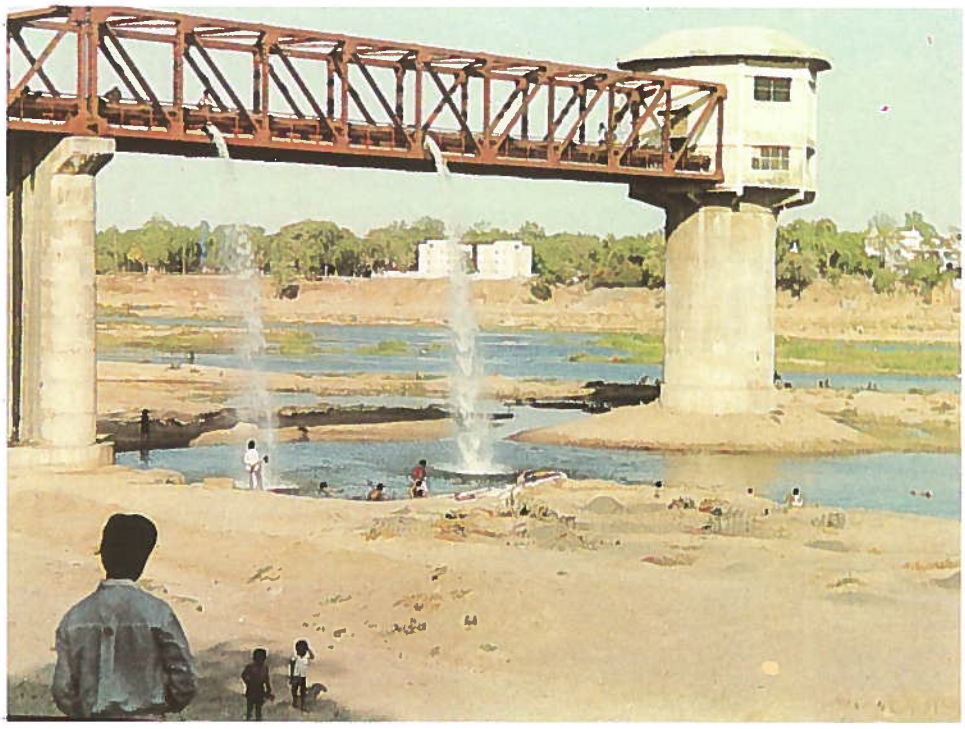
GoFlo Seawater Sampler (capacity : 100 l), used for ocean circulation studies using radiocarbon. (a) Empty sampler ready to go down and (b) sampler filled with seawater brought up from greater depths.

Laboratory in Research Vessel Sagar Sampada of the Dept. of Ocean Development, where CO_2 is recovered quantitatively from ~ 100 l water into 250 ml sodium hydroxide solution.

Nal Sarovar during dry season showing mud cracks. The sedimentation rate in these top layers has been estimated using ^{137}Cs.

Abundance of Gastropod shells in a layer exposed during trenching to study palaeoclimatic history of Nal Sarovar.

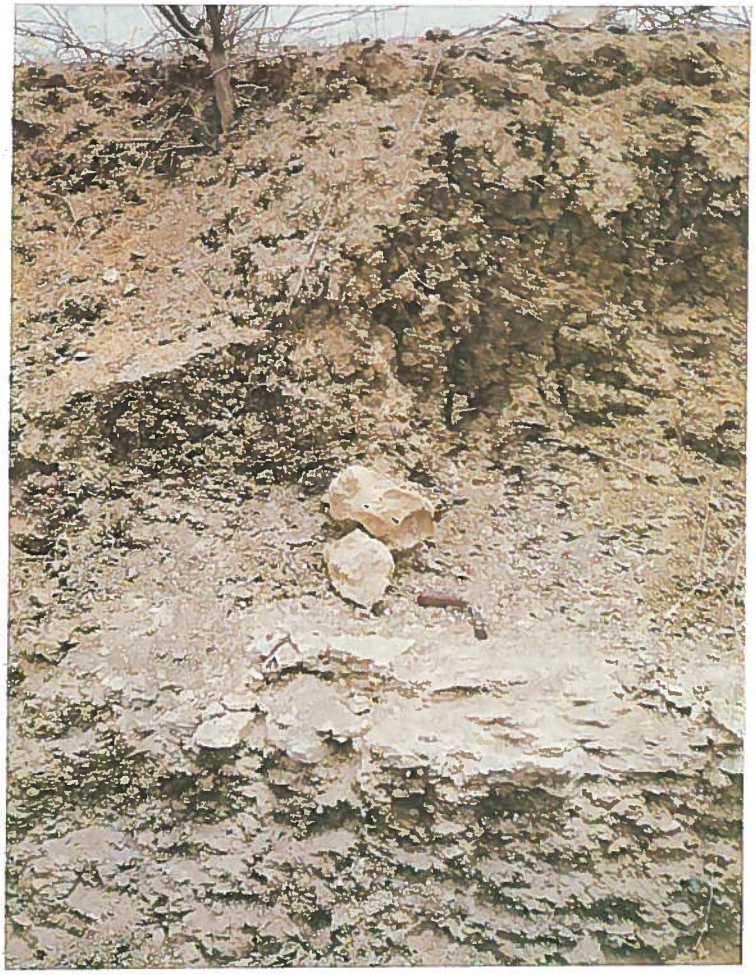
Tracer solution being prepared for tracer tests to see if there exists a rapid channel type flow between the sewage poll and the radial collector (French) well seen in the background.



The bridge and the central collector well of the Sabarmati French well during tracer testing.

(a)

(b)



Anjar Dinosaur pit section near Bhuj in Kutch. Sauropod bones have been found in section (a) were three thin brown Iridium rich layers (I, II and III) have been identified just above Dinosaur bone horizon. (b) shows transported fossil vertebrae of Dinosaurs above layer I in limestone.

station are presently being measured with the objective of quantifying air-sea exchange of CO_2 and its relation to wind speed and biological productivity in the Arabian Sea. Analysis of the first set of samples collected during 1993 for $\delta^{13}C$ and $\delta^{18}O$ of CO_2 and abundances of trace gases CO_2 , CH_4 , N_2O and CO show that Cape Rama is an excellent site from the point of view of sample integrity and homogeneity. For example, the sample to sample variations based on 11 sets of 4 samples collected in succession in an hour (from February 1993 to February, 1994) were : ± 0.5 ppmV (CO_2), ± 1 ppbV (CH_4), ± 0.2 ppbV (N_2O), and ± 1.5 ppbV (CO). The mean values over 1993 for abundances of these gases were: 356 ppmV (CO_2), 1790 ppbV (CH_4), 312 ppbV (N_2O) and 160 ppbV (CO). The CO_2 , CH_4 and CO contents in this station along with $\delta^{13}C$ of CO_2 show interesting seasonal variability (Fig. 3.1) which is being investigated at present. Recently an improved sample collection system has been designed to monitor wind speed and direction during the sampling. These studies form a collaborative research effort between the Physical Research Laboratory, Ahmedabad; National Institute of Oceanography, Goa (Dr.D.V. Borole) and CSIRO, Melbourne, Australia (Dr. Roger Francey).

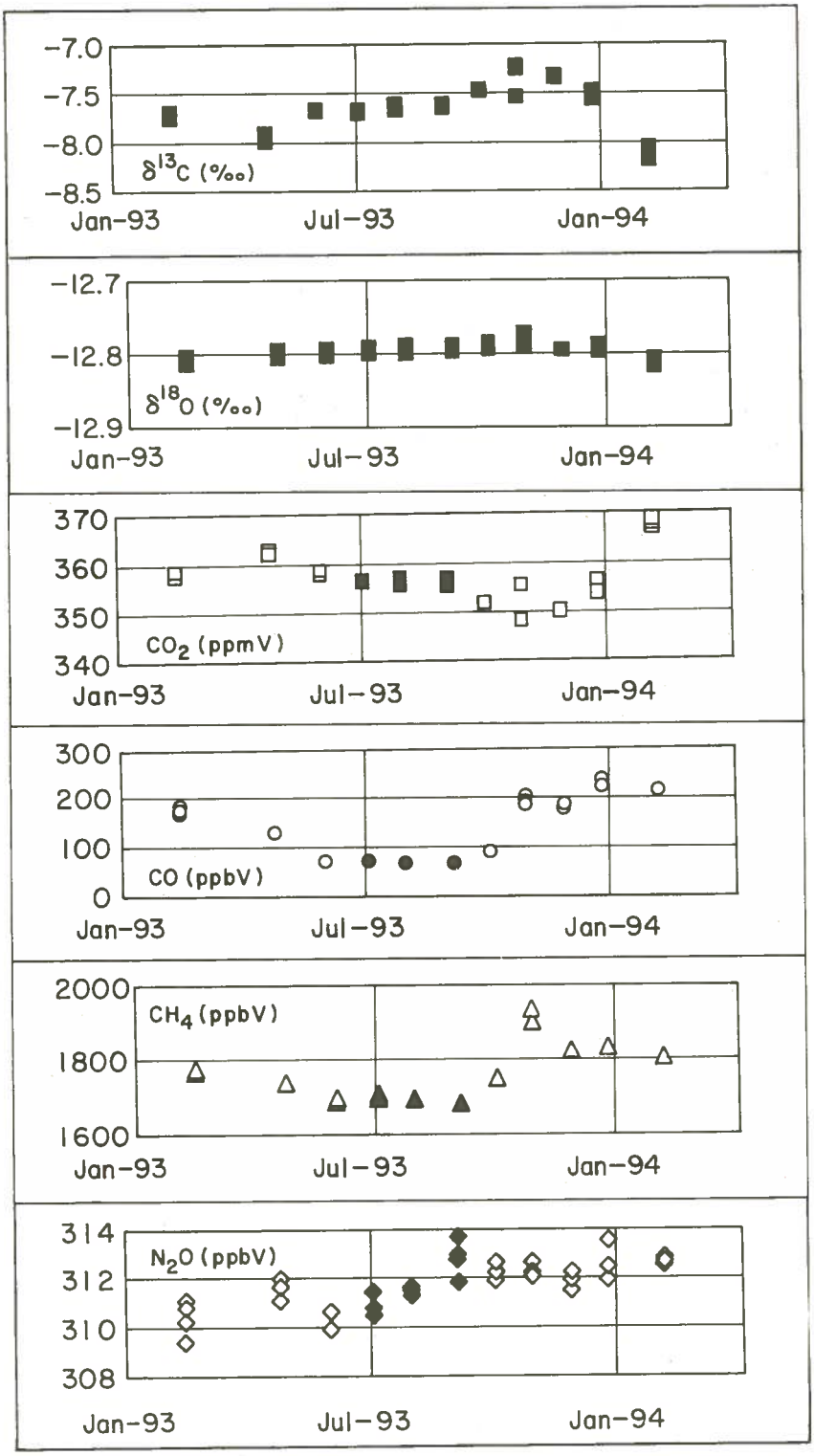
The second approach involves measurement of the partial pressure of CO_2 and other trace gases in sea water and air and using this data in conjunction with gas exchange coefficients to estimate air-sea gas exchange fluxes. This method is being followed as a part of national JGOFS programme, jointly with scientists from the Planetary Sciences Division. Towards this, measurements of trace gases in the water column are being made on board Indian research vessels during JGOFS cruises. The first such cruise took place during April-May, 1994. These studies will complement the atmospheric measurement at Cape Rama. In addition, the trace gas studies at Cape Rama will provide important time series data on the variation of their abundances for the first time from a monsoon dominate tropical zone. These projects therefore will prove valuable in estimation of air-sea exchange of CO_2 and its effect on the global carbon cycle.

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

Ocean Circulation and Mixing

Studies on the circulation of water in the seas adjacent to India viz. the Arabian Sea and the Bay of Bengal was initiated last year. This programme aims to determine the mixing parameters (diffusion coefficients and advection velocities) in the thermocline and the deep sea using Ra isotopes (for the thermocline) and ^{14}C (for deep sea). Three cruises to the Arabian Sea were conducted during May, 1993, January-February and February-March, 1994, wherein all the ship board operations have been streamlined. These involve collection and on-board processing of 100 litres of water from at least 10 depths in a profile for quantitative CO_2 extraction for ^{14}C measurements. In addition, large volume of marine air was sampled for quantitative extraction of CO_2 for atmospheric radiocarbon measurements. The laboratory processing and assay of radiocarbon have also been standardised. Preliminary results show that ^{14}C values range from +35 to +60 ‰ in the mixed layer and decrease with depth to a few per mil at 150 m. These values are lower than the corresponding values measured 17 years ago during the GEOSECS expedition. This reduction is due to mixing and dilution in the upper layers of the ocean. Analysis of Ra isotopes is now in progress.

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



3.1 Abundance of Trace gases CO_2, CO, CH_4 and N_2O and isotopic composition of carbon $\delta^{13}C$ (in CO_2 gas) in samples collected from the Cape Rama Station in Goa (15° N, 73° E) during 1993.

Mid-Holocene Sea Levels Along the Saurashtra Coast

Carbonate shell samples from geomorphologically controlled locations along the Saurashtra coast were dated using radiocarbon to ascertain sea level changes during the Holocene. Oyster samples were collected from their growth positions between 1 m to 3 m above sea level. The radiocarbon ages of these samples range from 2 to 5 kyr B.P. The results suggest that sea level gradually receded to the present level after the mid-Holocene. The estimated rise of 1.5 m after appropriately correcting for tectonic movements, has been ascribed to the mid-Holocene transgression. The above results are in conformity with the observations on other tropical coasts.

(N. Juyal, S. Kusumgar, R.K. Pant and M.G. Yadava)

Climate Related Studies

One of the main objectives of the area's programme is to retrieve climatic and environmental information contained in a variety of continental and marine repositories on different time scales and resolutions. The repositories sampled include tree rings, coral and glaciers for high resolution, lake and coastal sediments for decadal to century scale resolution and deep sea and other continental land forms for long term, coarser resolution records. Below we describe some of the important results obtained from these samples.

Glaciers and Glacier Deposits

With a view to understand the dynamics of glacier ice and the chemical composition of recent snow/ice, we analysed several samples collected at various altitudes and locations from the Himalayan glaciers, Dokriani and Bamak. The results indicate that - (i) the maximum surface ice transfer on this glacier takes place at the equilibrium line as compared to average surface ice transfer (18 m/yr) all along the glacier; (ii) the radiometric age of the surface snout ice is determined to be about 300 years based on a two component model using ^{32}Si and ^{210}Pb . It is expected that the glacier may contain records of short term climatic changes, covering the time span of little ice age ; (iii) the major ions Na and Cl deposited on the glacier are transported from the marine source whereas the Ca and SO_4 are derived primarily from the terrestrial sources.

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

Another topic of current interest in glaciology is the study of Quaternary glaciation in Central Himalaya. The Equilibrium Line Altitude (ELA) of a glacier is climate sensitive and fluctuates in response to local radiation, temperature and precipitation. The highest elevation of the lateral moraines provide the extent of ELA depression associated with former glacial advances. The altitudinal difference in modern and past ELA can be used to estimate temperature decline and possibly change in the precipitation regime in the past. Towards this end geomorphological techniques, remotely sensed data such as IRS imageries, Survey of India topographic sheets are being used to identify glacial features in the Central Himalaya to estimate ELA fluctuations. ELA of the modern glaciers in the Goriganga basin, District Pithoragarh, UP, lies at 4700 m altitude. Relative to this level three former glacial advances could be identified by this technique; these correspond to ELA declines of 500 m, 400 m and 200 m respectively. Chronology of these glacial advances is presently being worked out.

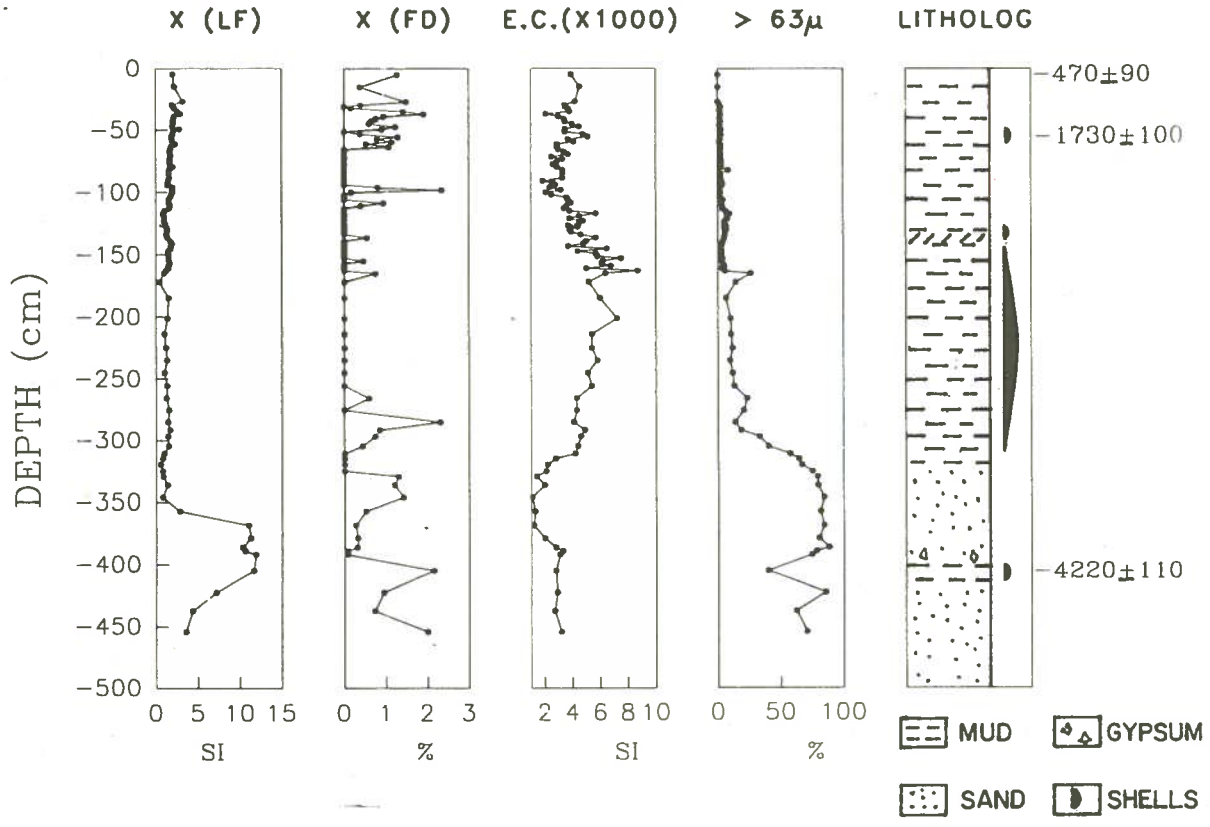
(N. Juyal and R.K. Pant)

Lake Sediments and Soil Profile

Investigations of the 53 m long core collected from the Nal Sarovar during the summer of 1992 were continued. The Nal Sarovar lies on the fringe of the desert area in a semi-arid climate and is the only large closed lake basin in this part of the country. We expect that the climatic indicators may have been amplified because of the geographic and physiographic setting of the Nal Sarovar.

Radiocarbon dating of the carbonate nodules recovered from the lowermost section (18-53 m) indicated that this section was deposited prior to 38 kyr. Possibilities of good chronological controls, through radiocarbon dating, led us towards detailed studies of the upper 5 m of the core (Fig. 3.2). Magnetic susceptibility studies in this section did not indicate any significant depth variation except in a horizon around 4 m depth which shows a clear evidence of a change in provenance of magnetic minerals. The radiocarbon age measured on organic fraction for this horizon is about 4.4 kyr. Depth variation in the coarse fraction of sediment (> 63 μ) indicates that the mean grain size of the layers having abundant shell population are predominantly finer. Implications of these characteristics are being synthesised.

The soluble salt content of the sediments increases between 1.3 m to 3 m and 3.75 m to



3.2 Depth variation in magnetic susceptibility grain size and soluble salt content together with radiocarbon dates and lithostratigraphy in top 5m of Nal Sarovar core.

4.5 m. sections. These increases surprisingly correlate with increases in the abundances of gastropod shells in these two zones. It is suspected that these horizons represent periods in which the climate was relatively dry. Efforts to obtain more definitive chronology and palaeoclimatic information through thermoluminescence dating, radiocarbon measurements and stable isotopic studies of the organic carbon and carbonate shells are in progress.

(S.K. Gupta, S. Kusumgar, S. Prasad, A.K. Singhvi and M.G. Yadava)

During the course of work at Nal Sarovar, we had an access to a 12.2 m long late Quaternary subsurface sedimentary sequence at Vastrapur, Ahmedabad (about 70 km north-east of Nal Sarovar). Samples at regular interval of 30 cm were collected from the sequence to study palaeoenvironmental parameters and compare the results with Nal Sarovar data.

The grain size analysis shows that it comprises of medium sand at the bottom (below 8.5 m) changing to fine sand in the middle (8.5 to 4.6 m) and very fine sand in the top 4.6 m. Three poorly developed palaeosols and a number of horizons containing $CaCO_3$ nodules were observed. Based on the grain size distribution studies it is inferred that the section below 4.6 m depth, comprising medium to fine sand may be of aeolian origin. Studies of magnetic susceptibility indicate that in the sequence below 4.6 m it is correlated with the proportion of fine grained particles whereas it is anti-correlated with the proportion of fines in the top 4.6 m; this suggests different sources for the sediments in the two horizons. In the entire section the frequency dependent component of susceptibility is small and does not indicate any significant proportion of pedogenically produced ultrafine ferrimagnetic grains.

Carbon and oxygen isotopic studies ($\delta^{13}C$ and $\delta^{18}O$) on the carbonate nodules yield values in the range of - 0.3 to - 6.3 for $\delta^{13}C$ and - 4.4 to - 5.3 for $\delta^{18}O$ (in ‰). The $\delta^{18}O$ values are lower than expected for modern nodules in this zone. One possible explanation for the observed low $\delta^{18}O$ values is that these nodules were precipitated from percolating rainwater with lower $\delta^{18}O$ content than the average of the modern rainfall in the region. This would in turn suggest either lowering of temperature or increase of precipitation. The carbon isotope data suggest possible change in vegetation with increased C_3 type of plants. More data are needed to understand these systematics quantitatively. Analysis of the Ahmedabad sequence will complement the picture emerging from the Nal Sarovar study to make a regional scenerio.

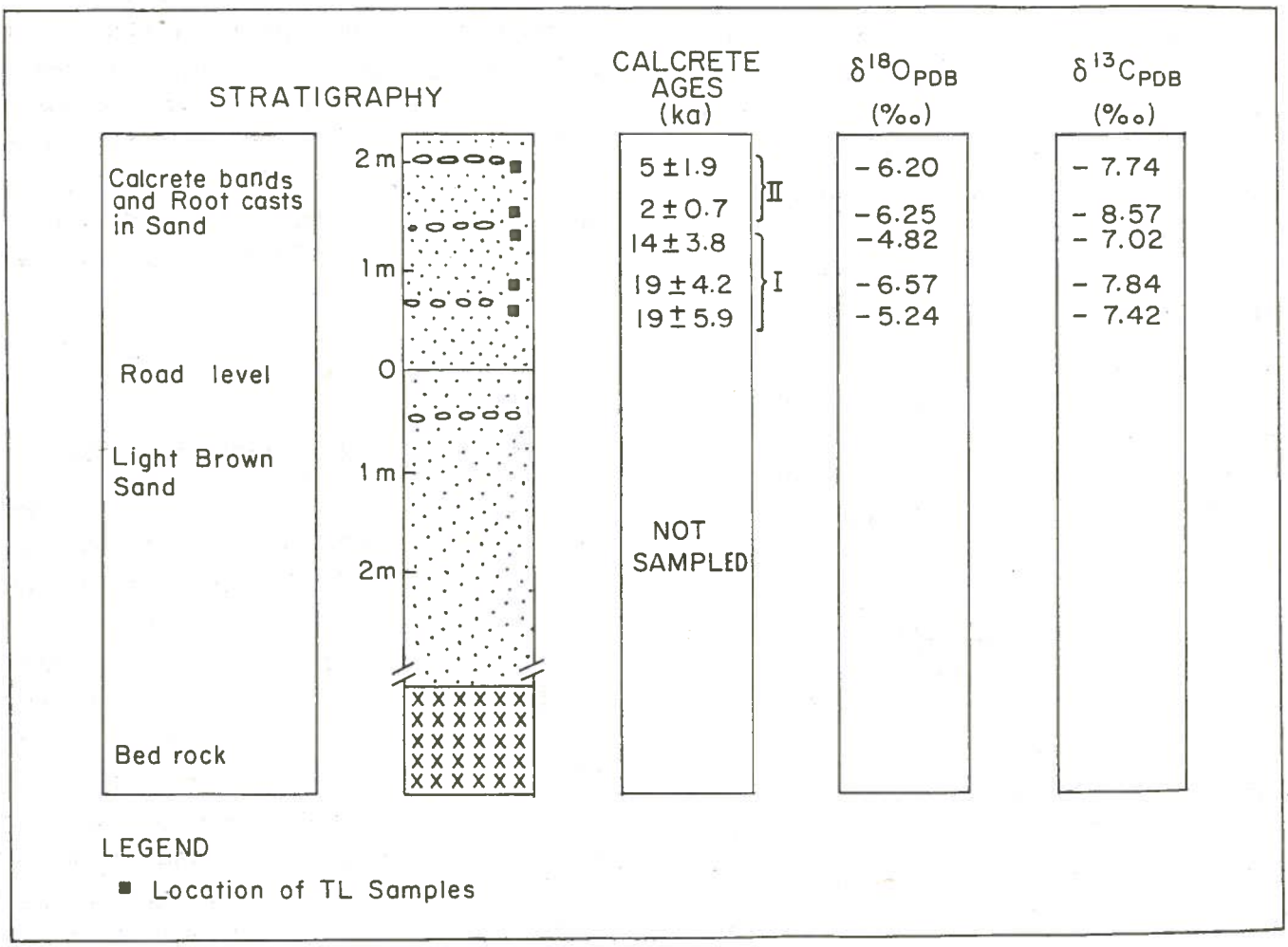
(S. K. Bhattacharya, R. Deshpande, S. K. Gupta and R.A. Jani)

Sand and Calcretes from the Thar Desert

Studies on the evolution of the Thar Desert were continued. Two major dune profiles in the western extremes of the Thar Desert, viz. Barmer and Pushkar in east central Thar were examined. The Barmer sequence at village Kudala extends to 81 ka with three periods of higher sand accumulation centred around 81 ka, 35 ka, and 17 ka. The intervening periods of low sand accumulation results from complex interplay of wind speed, sand supply and vegetation cover which in turn are related to changes in past monsoonal conditions and sea-level changes resulting in change of sand supply from the exposed beaches. This sequence overlies a gravel bed rich in palaeolithic tools. The TL age of 81 ka for

the lowest part of the sequence implies that the tools are older than 81 ka; this result is in contrast with the (40-50) ka age conventionally assumed by archaeologists. The sequence at Pushkar has been studied earlier in detail and its stratigraphy is known to be regionally correlatable. We have re-examined the site for TL dating. Our results suggest that the earlier chronologies and climatic interpretation of a wet - middle palaeolithic period based on archaeological considerations and soil analysis are not tenable. Instead - only a semi-arid regime during the past 25 ka is inferred.

A significant new development made by the group was towards the dating of pedogenic calcretes. Calcretes are an important geomorphic feature of arid-zones of the world and have been considered important climate indicators. There are questions regarding their role in influencing CO_2 content of the atmosphere. A major hurdle in using these deposits to obtain palaeoclimatic information is the difficulty associated with the determination of their chronology. They are known to behave as open system in respect of radiocarbon and U/Th isotopes and hence these



3.3 Aeolian stratigraphy at Pushkar along with calcrete ages and stable carbon and oxygen isotope data. The age inversion of 5 ka and 2 ka horizon probably occurred due to a lower precipitation at ~ 5 ka compared to that at 2 ka implying greater leaching depth.

radiometric methods are not quite useful to determine their ages. The new method proposed by us is based on luminescence of carbonated minerals. This is largely immune to post-depositional geochemical changes as it utilises changes in total dose to a quartz grain in a sediment consequent to its being carbonated. The range of β-rays (~ 1-2 mm) provides the spatial limits beyond which any geochemical alterations would not affect the dose rate . Luminescence ages of a suite of carbonate root casts from Pushkar (Fig.3.3) cluster around 17 ka. Carbonate from upper horizons are dated to ca. 5 ka and ca. 2 ka. These ages appear plausible from climatological aspects since characteristically pedogenic carbonates form in regions of net annual moisture deficit with seasonality and annual precipitation of < 400 mm. Oxygen isotopic ratios in Pushkar carbonates range from - 4.8 ‰ to - 6.6 ‰ (relative to PDB) and suggest that they were formed primarily from leaching caused by monsoonal precipitation. The carbon isotopic values range from - 7.0 to - 8.6 ‰ which based on model calculations suggest a contribution of upto 65% C_3 plants indicating wetter periods. A synthesis of lacustrine record of Thar and deep sea record from the Indian Ocean indicates that conditions suitable for carbonate precipitation should have occurred during 20 ka to 12 ka, 6 ka to 4 ka and 3 ka to present. The ages obtained by us fall in these broad age brackets.

On a technical front this year we established Optically Stimulated Luminescence (OSL) dating at PRL (and in India) using indigenously developed system. A suite of six samples from aeolian sands of the Thar desert, palaeo-fan sequence incised by the Sabarmati river and glacier moraines were studied and all of these provide results consistent with those using TL. A multiple sample OSL system has now been developed for speedier analysis.

Besides these studies, several dune sequences from Iran were dated yielding ages in the range of 50-200 ka. Similarly a suite of aeolianites from Oman gave ages in the range of 13 to 100 ka. A global synthesis of chronology of aeolian accumulation is being attempted to understand the response of these climatically sensitive zones to glacial - interglacial fluctuations. The research on desert sequences was done in collaboration with scientists from CAZRI, Deccan College, Delhi University, University of Tubingen, University of Teheran and the Geological Survey of India and Dr. M. Lamothe.

(D. Banerjee, Navin Juyal, R.K. Pant, R. Ramesh, A.K. Singhvi and M. Someshwar Rao)

Palaeosol Carbonates and Climate during the Upper Cretaceous

In Central India, a sequence of calcareous sediments of Upper Cretaceous age, known as the Lameta Formation, is exposed beneath the Tertiary Deccan Traps. Extensive soils developed on these sediments leading to the formation of pedogenic carbonates. These pedogenic carbonates were analysed for oxygen and carbon isotopic composition to infer the palaeometeorological and palaeovegetational regime in central part of the Indian continent. The oxygen isotope composition of these carbonates ranges from - 6.7 to - 8.9 ‰. These data in conjunction with standard isotope fractionation model yield for the isotopic composition of the meteoric water a value of - 8 ‰ (w.r.t. SMOW) in Cretaceous Central India. This value is considerably

lighter compared to the composition of modern precipitation in Central India, i.e. about - 3 ‰.

The lighter isotopic composition of the meteoric water relative to contemporary values signifies the different nature of the meteorological system operating at that time, resulting from the palaeogeographical position of a probably larger size Indian land mass. The low value of $\delta^{18}O$ can best be explained by a combination of effects arising from highly seasonal (monsoon-like) and more intense rain fall regime in a rain shadow zone and a more pronounced continental effect due to a bigger size of the Indian continent.

The carbon isotopic composition of the Lameta carbonates range from - 7.1 to - 10.7 ‰ with average of - 9.1 ‰ suggesting a series of soils dominated by C_3 type of vegetation. These data yield for the average composition of the vegetation a value of - 23.4 ‰ which is about 3 ‰ enriched compared to the modern day C_3 vegetation. This can be explained in terms of mixing of atmospheric CO_2 ($\delta^{13}C$ = - 6.5 ‰) with soil CO_2. Material balance requires that about 15% contribution of atmospheric CO_2 to the CO_2 in the soil would explain the observed 3 ‰ enrichment. This contribution of atmospheric CO_2 allows one to estimate the partial pressure of CO_2 in the Late Cretaceous atmosphere under certain assumptions. The palaeo-pCO_2 level at that time is estimated to be 1000 to 2000 ppmV. If this inferences is confirmed through future studies this will suggest that the pCO_2 decreased monotonically from 2500 ppmV to 300 ppmV from early Cretaceous to Holocene. This work was done in collaboration with Mr. P. Ghosh of Indian Statistical Institute, Calcutta.

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

Palaeoceanography with ^{10}Be

Cosmic Rays interact with the earth's atmospheric constituents N_2 , O_2 and Ar producing a variety of radionuclides with varying half lives of which ^{10}Be (half life = 1.5 m.y) is an important one. Subsequent to its formation ^{10}Be is deposited on land and ocean surface mainly via precipitation. ^{10}Be is removed from the surface sea water by absorption on to particles on short time scales and deposited on sediments. ^{10}Be measurements have become routine and easy with the advent of Accelerator Mass Spectrometry. This has considerably enhanced the scope of ^{10}Be as a tracer to study a variety of earth surface processes. One such process of interest to climatology is the discharge of meltwater during the interglacials into the oceans.

This application relies on the fact that the most concentrated solution of ^{10}Be on Earth is rain (and in solid form as snow/ice) During glacial times snow/ice accumulate on the Earth's surface for long intervals creating a ^{10}Be store house. During interglacial periods, the ice/snow melts and the meltwater containing high concentration of ^{10}Be flood the ocean. The ^{10}Be thus introduced as a pulse gets removed by the detrital particulate material to sediments in times shorter compared to the mixing time of the ocean (i.e. 1000 years). Therefore, such ^{10}Be pulses, if located in sediment column, would provide information on melt water inputs and their time scales. As a first step studies are done along with $\delta^{18}O$ which is another established tracer for identifying melt water influx.

In the Gulf of Mexico sediments a strong negative correlation (r = - 0.95) between $\delta^{18}O$

(range -1.5 ‰ to 0.8 ‰) and $^{10}Be/Al$ is obtained. Similarly $^{10}Be/Al$ measurements were made in cores from the Mediterranean sea and the Arctic. The core from the Arctic was not dated but its glacial horizons could be identified by comparing with $\delta^{18}O$ stratigraphy of a neighbouring core. These data (fig. 3.4) show that, as expected, the glacial sections have low $^{10}Be/Al \sim (2\text{-}4) \times 10^9$ atoms/g in contrast to the interglacial sections (8-10) x 10^9 atoms/g. Further analysis is in progress.

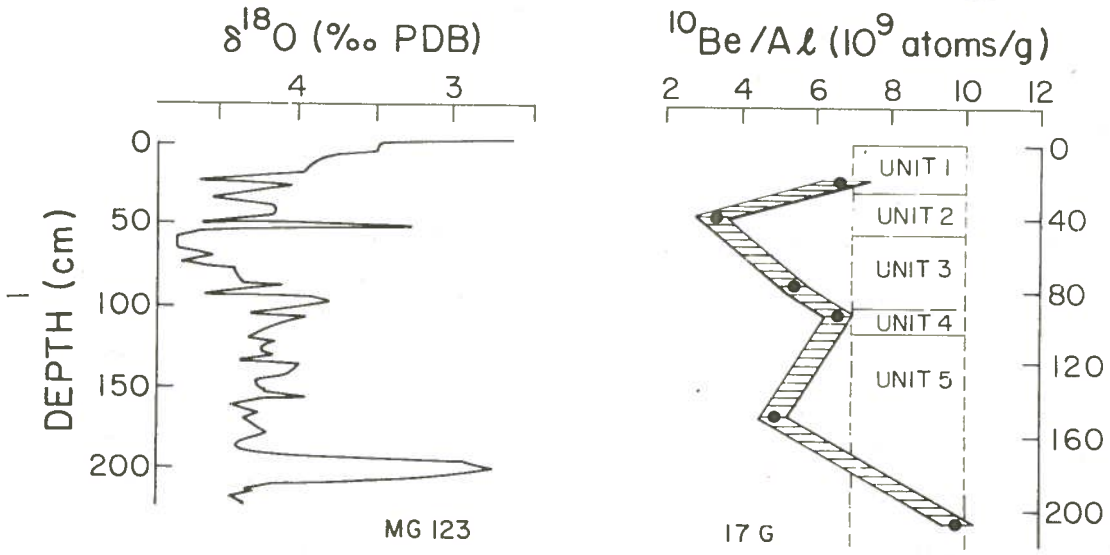
(B.L.K. Somayajulu)

Hydrology and Weathering

Investigations into Contamination of the French Wells at Ahmedabad

In September, 1992, bacterial and fungal contamination was detected in the collector wells located in the Sabarmati River bed at Sabarmati and Acher in north Ahmedabad. These wells, also known as French wells, have been in operation for almost a decade supplying potable water for the city of Ahmedabad. The question therefore, naturally, was : why was the contamination observed only now eventhough the sewage discharges into the river have existed for several years ?

To answer this question, three types of investigations were undertaken : (i) a tracer test designed to ascertain if there existed a rapid channel type of flow between the visible sewage discharge points and any of the radials of the collector well, (ii) a step draw-down pumping and recovery test to understand the systematics of the French well-river bed system in relation to the surface flow conditions of the river, and (iii) physico-chemical and bacteriological analyses of the river bed aquifer to ascertain the extent of river bed contamination.



3.4 $^{10}Be/Al$ ratio as a function of depth in core 17G from the Arctic Ocean. The lows and highs in the ratio compared with $\delta^{18}O$ of a neighbouring core. High $^{10}Be / Al$ are relatable to low $\delta^{18}O$ and vice-a-versa.

The tracer test comprised of injecting 100-200 kg of sodium salts (NaF, NaBr and Na_2SO_4) at three locations around (within 100-600 m) the Sabarmati French well and subsequent monitoring for about a week for the presence of these chemicals in the pumped out water. No definite increase in concentration of tracer ions was observed beyond what could be accounted for by natural fluctuations in the river water chemistry. These results suggested absence of channel type of flow from pollution sources to the collector wells. Bacterial contamination was, however, observed in the pumped out water from the French wells.

To estimate the hydraulic properties of the river bed aquifer around the two French wells and to study the mechanism of flow of water to the two collector wells, step draw-down pump test was carried out in the Sabarmati and Acher French wells.

Computer models based on available theory of flow of groundwater to collector wells were developed. Step draw down and recovery test data of the Sabarmati and Acher French wells were used to calibrate the computer models and refine the hydrological parameters in the aquifer. The calibrated models were used to estimate the radius of influence and the travel time of water drawn at different distances from the collector wells.

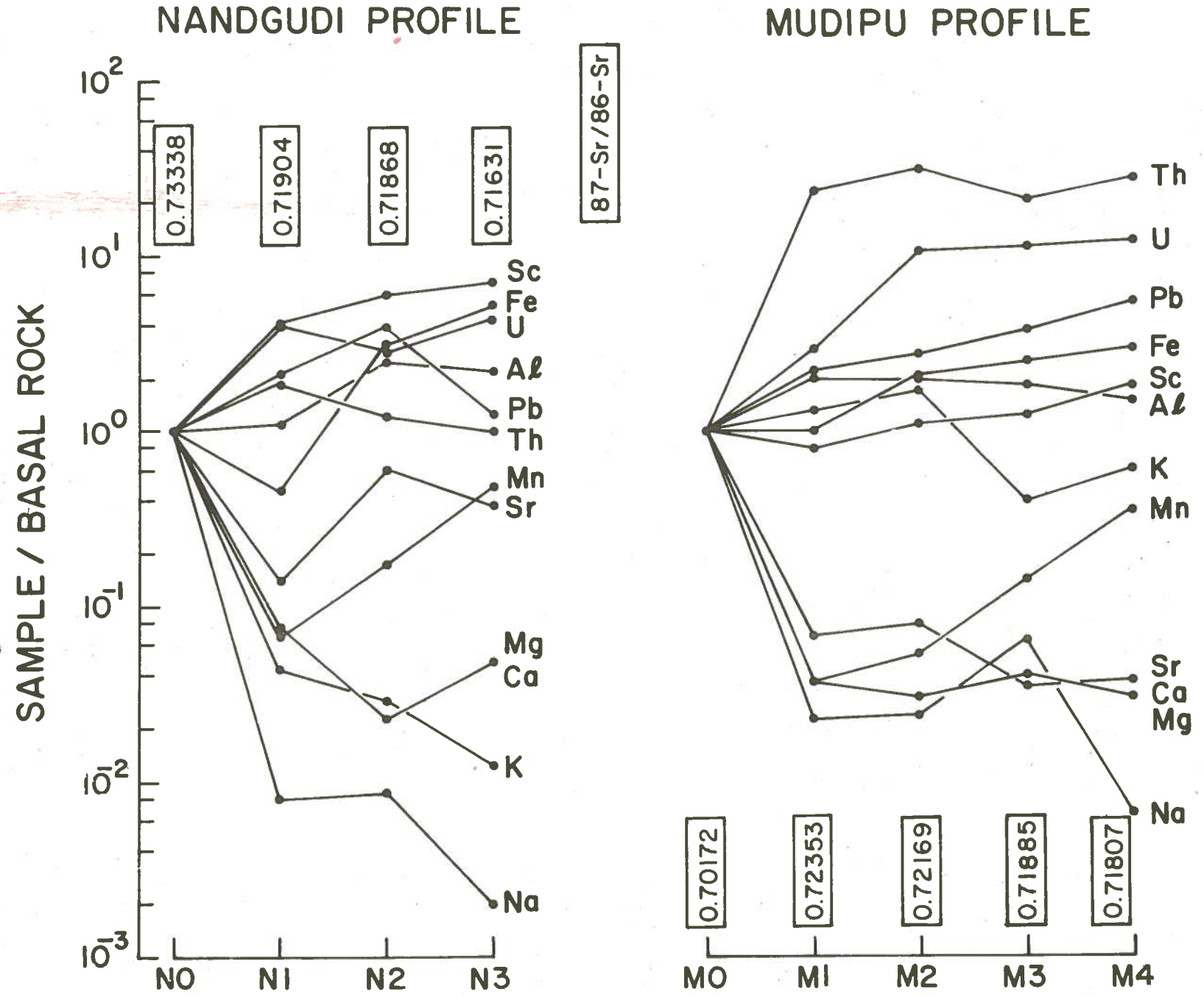
Results indicate that the Sabarmati river bed aquifer is highly anisotropic with vertical permeability being only about 6 % of the horizontal permeability. This is further confirmed by the grain size distribution of the sediment samples collected from the three bore holes drilled in the vicinity of the collector well as part of these investigations. Modelling study of the pump test data suggests that the observed contamination of water pumped from the two collector wells was caused not by any channel type of flow due to disturbance of strata during the previous floods but by slow and steady migration of pollution front through years of persistent sewage discharge and growth of fungi. This was confirmed by physico-chemical and bacteriological investigations of four bore hole samples drilled in the vicinity of the Sabarmati French well. Coliform bacteria and faecal streptococci were present upto 12 m depth, where the radials of the two wells are located. This confirmed the conclusion drawn from tracer and modelling studies that the contamination of the collector well water at Sabarmati was the result of slow but steady migration of the river bed pollution over the years. This work was done in collaboration with Mr. P. Nema of NEERI, Ahmedabad Zonal Laboratory.

(S.K. Gupta, M. M. Sarin and P. Sharma)

Laterites : Their Chemical and Isotopic Composition

Three vertical profiles of laterites each comprising of three to five samples have been analysed for thirty elements (major and trace), including eleven REE, U-Th decay series nuclides and $^{87}Sr / ^{86}Sr$. Two of the profiles were collected from the coastal town Mangalore (annual rainfall ~ 250 cm) and one from inland of Bangalore city (annual rainfall ~ 75 cm) both in the state of Karnataka, southern India. The measured chemical and isotopic composition of the laterites at various stages of their evolution are compared with those of the basal Archaean rocks to understand elemental mobilisation during lateritisation.

The concentrations of Al, Fe, U and Th in the laterites are higher by factors of about 2 to 30



3.5 Select element / rock ratios and $^{87}Sr/^{86}Sr$ ratios in vertical section of two laterite profiles from Nandgudi (left) and Mudipu (right) in Karnataka. Notice the enrichments (ratios >1) and depletions (<1) of elements and decrease in $^{87}Sr/^{86}Sr$ (numbers in rectangles) during lateritisation.

relative to the basal rocks whereas Mg, Ca, Mn and Cu are depleted by similar factors (Fig.3.5). The light REE in the laterites get depleted more than the heavy and the positive Eu anomaly which is present in the basal rock disappears in the laterites. The whole rock Sr-87/Sr-86 = 0.70172-0.751138 is much less than that in laterites 0.72353-0.75182 indicating the retention of the more resistant K and Rb rich minerals during lateritisation. These observations are consistent with our current understanding of mineral weathering in rocks.

In the ^{238}U decay series, significant radio-active disequilibrium was observed between ^{230}Th and ^{234}U (^{230}Th / ^{234}U ~ 0.2 to 1.1), ^{226}Ra and ^{230}Th ($^{226}Ra/^{230}Th$ ~ 0.8-4.5) and ^{210}Pb and ^{226}Ra ($^{210}Pb/^{226}Ra$ ~ 0.8 to 1.1). The gross disequilibrium in the Th-230/U-234 and Ra-226/Th-230 which have about 400,000 and about 10,000 years equilibrium time scales respectively, suggest that lateritisation is an ongoing process in the Karnataka. The Pb-Ra disequilibrium can be atttributed to gaseous radon loss. This work is being carried out in collaboration with Drs. K. Gopalan of NGRI and B.P. Radhakrishna of the Geological Society of India, Bangalore.

(R. Rengarajan, M.M. Sarin and B.L.K. Somayajulu)

Modelling

Rayleigh Isotopic Fractionation from a Multi-component Source.

The study of the isotopic composition of various minerals in rocks can provide clues to the sources contributing to their isotopic make-up. This is because the isotopic compositions of constituent minerals of a rock are determined by the temperature, pressure and the degree of melting/crystallisation during their formation. Rayleigh isotopic fractionation is generally used to understand the isotope systematics in geology. As minerals may derive their isotopes from several components in the source, we have derived a Rayleigh fractionation equation for a source with multiple components (L components) which can be written as :

$$\delta - \delta_o = 10^3 \; [(\alpha_{c1} / a) \ln \{ (af-b)/(a-b) \} - \ln (f)]$$

where a is the weighted mean of the fractionation factors between the different source components and the first source component, the weight being the number of atoms (p_j) of the element contributed by each source component to the mineral formed (denoted by subscript c); b is the same as a, except that the weight now includes the critical value of f (i.e. f_j) when the particular source component gets exhausted and α_{c1}, the fractionation factor between the mineral formed and the first source component. Mathematically, these are : $a = (1/P) \Sigma(p_j \alpha_{j1})$ and $b = (1/P) \Sigma(p_j f_j \alpha_{j1})$ where P is sum over p_j for all j's (1 to L) i.e., the total number of atoms of the element (the fractionation of the isotopes of which is being considered) in the mineral formed. f_j is given by:

$$f_j = 1 - P \; r_{j1} / \Sigma (p_j r_{j1})$$

Here, r_{j1} denotes the ratio of the initial number of moles of the j^{th} component to that of the first component in the source.

Carbonatites are derived from the mantle. They can form by either combining CaO and mantle CO_2 or by Ca, CO_2 and H_2O. Figure 3.6 shows the application of our model to the carbonatite isotopic evolution. $\delta^{13}C$ is plotted against $\delta^{18}O$, for two cases where the mole ratios of H_2O to CO_2 are 0.2 and 0.7 respectively. Arrows

show the discountinuities when the H_2O reservoir is exhausted.

This model will be very useful to explain the oxygen and carbon isotopic composition of mantle derived rocks like carbonatites especially when multiple (i.e. more than two) reservoirs of oxygen and carbon present in the magma are involved in the genesis of these rocks. Isotopic measurements of carbonatites from several parts of India are in progress. This model will help to analyse these data and derive their mantle sources.

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

Radiocarbon Dating

The radiocarbon laboratory which is recognised as a National Facility carried out 90 measurements during 1993 and provided impor tant ^{14}C dates in various studies related to archae ology and palaeoclimatology.

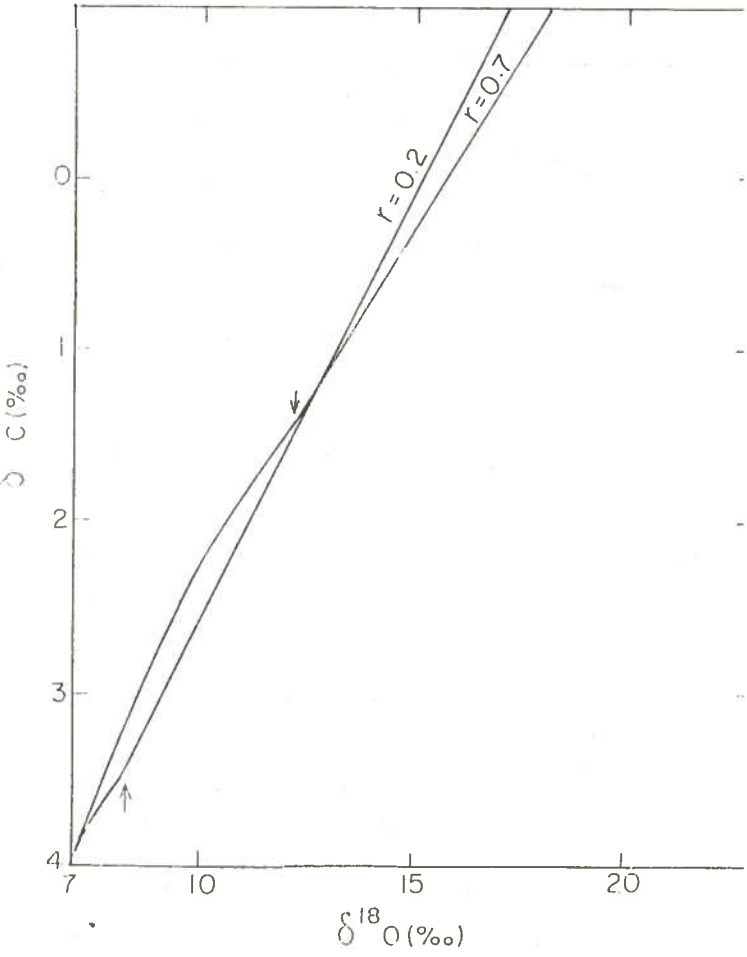
In addition, we have participated in the Thi d Intenational Radiocarbon Intercomparisc n Programme. Following the international proc - dures different types of material like peat, trave - tine, turbidite and wood (total 6 samples) wer assayed in 35 laboratories around the world. I most cases, the PRL results compare well with th means of the distributions.

Archaeological Studies

There have been reports of non-Harappan chalcolithic cultures from Gujarat some of which seemed to be considerably old. ^{14}C dates going back to middle of third millenium B.C. have been obtained recently for chalcolithic culture of Loteshwar and a so-called pre-Harappan culture at Padri. These dates establish them as the oldest known chalcolithic cultures in India which have distinct identities unaffected by Harappan culture. They seemed to have grown from a local mesolithic culture.

We also analysed some samples from Orissa related to the wheel made pottery and beginning of copper metallurgy. The assigned ages for them correspond to the third millenium B.C.

A sample from Uleni in Kumaun gave an age of about 2700 years B.P. for the early iron technology. This suggests the distinct possibility that Kumaon could be a source of early iron for the painted greyware culture of the North India.



3.6 Carbon versus oxygen isotope variations in a carbonatite according to our model calculations for two values of H_2O/CO_2. Arrow indicates the discountinuity that sets in after the exhaustion of the water reservoir.

Sediment Studies

Four peat samples from a sediment core raised from the Bengal basin have been analysed to provide absolute chronology for the Holocene period. The preliminary results suggest that the location is characterised by a high sedimentation rate of 1.1 m/kyr. This opens up the possibility of high resolution palaeoclimatic reconstruction in Bengal basin. The pollen work on these cores are in progress under the supervision of Prof. S. Chanda of Bose Institute, Calcutta.

(S. Kusumgar and M.G. Yadava)

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1 Chakrabarti, A., Somayajulu, B.L.K., Baskaran, M. and Kumar, B., "Quaternary miliolites of Kutch and Saurashtra : Depositional environment in the light of sedimentary biogenic structures and geochronological setting of the rocks", Senckenbergiana Maritima, **23**, 7, (1993).

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4 Nijampurkar, V. N., Sarin, M. M. and Rao, D.K., "Chemical composition of snow and ice from Chhota Shigri Glacier, Central Himalaya", J. Hydrology, **151**, 19, (1993).

5 Nijampurkar, V. N. and Rao, D. K., "Ice dynamics and climatic studies on Himalayan glaciers based on stable and radioactive isotopes",Snow and Glacier Hydrology, IAHS Publication No. 218, **355** , (1993).

6 Pant, R. K.," Spread of loess and march of desert in Western India", Curr. Sci. **64**, 11, (1993).

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13 Somayajulu, B.L.K., Martin, J.M., Eisma, D., Thomas, A.J., Borole, D.V. and Rao, D.K. , "Geochemical studies in the Godavari estuary", Mar. Chem., **43**, 83, (1993).

14 Sukumar, R., Ramesh, R., Pant, R.K. and Rajagopalan, G., "$\delta^{13}C$ record of late Quaternary climatic changes from tropical peats of South India", Nature, **364**, 703, (1993).

15 Thomas, D.S.G. and Singhvi, A.K., "Desert evolution, processes, climate and change: An introduction", J. Arid . Env., **1**, (1993).

SOLAR SYSTEM AND GEOCHRONOLOGY

The Earth Science and Solar System division was reorganised this year into two new areas to provide proper thrust and focus to the research problems. The Solar System and Geochronology Area is focussing on problems related to the early solar system which led to the formation of the Sun and the planets and to develop geochronological framework of major events on the Earth, specifically those related to the Indian lithosphere.

The effectiveness of this reorganisation is clear from the fact that several major breakthroughs have been accomplished in the Solar

System and Geochronology Area. Amongst them can be mentioned (I) The identification of Cretaceous/Tertiary boundary (KTB) layer within Deccan intertrappeans, which has provided a high resolution time sequence that has important implications to the relation of Deccan volcanism with the bolide impact. It has been shown that the peak activity of Deccan episodes and cometary or asteroidal impact are not inter-related events (II) Discovery of now extinct ^{41}Ca ($\tau_m = 1.5 \times 10^5$ years) in pristine solar system grains in meteorites which has put new constraints on the time taken ($<10^6$ years) since the last injection of freshly synthesised elements in the solar nebula and formation of the first solid grains in the solar system.

In addition, new research problems for developing a chronological framework of collision of Indian plate with Eurasian plate in Ladakh Himalayas was undertaken. A technique for estimating silver in 10^{-9} -10^{-12} g/g range by neutron activation technique was developed.Detailed report of the research activities follows :-

Boundary Events: Impact or Volcanism?

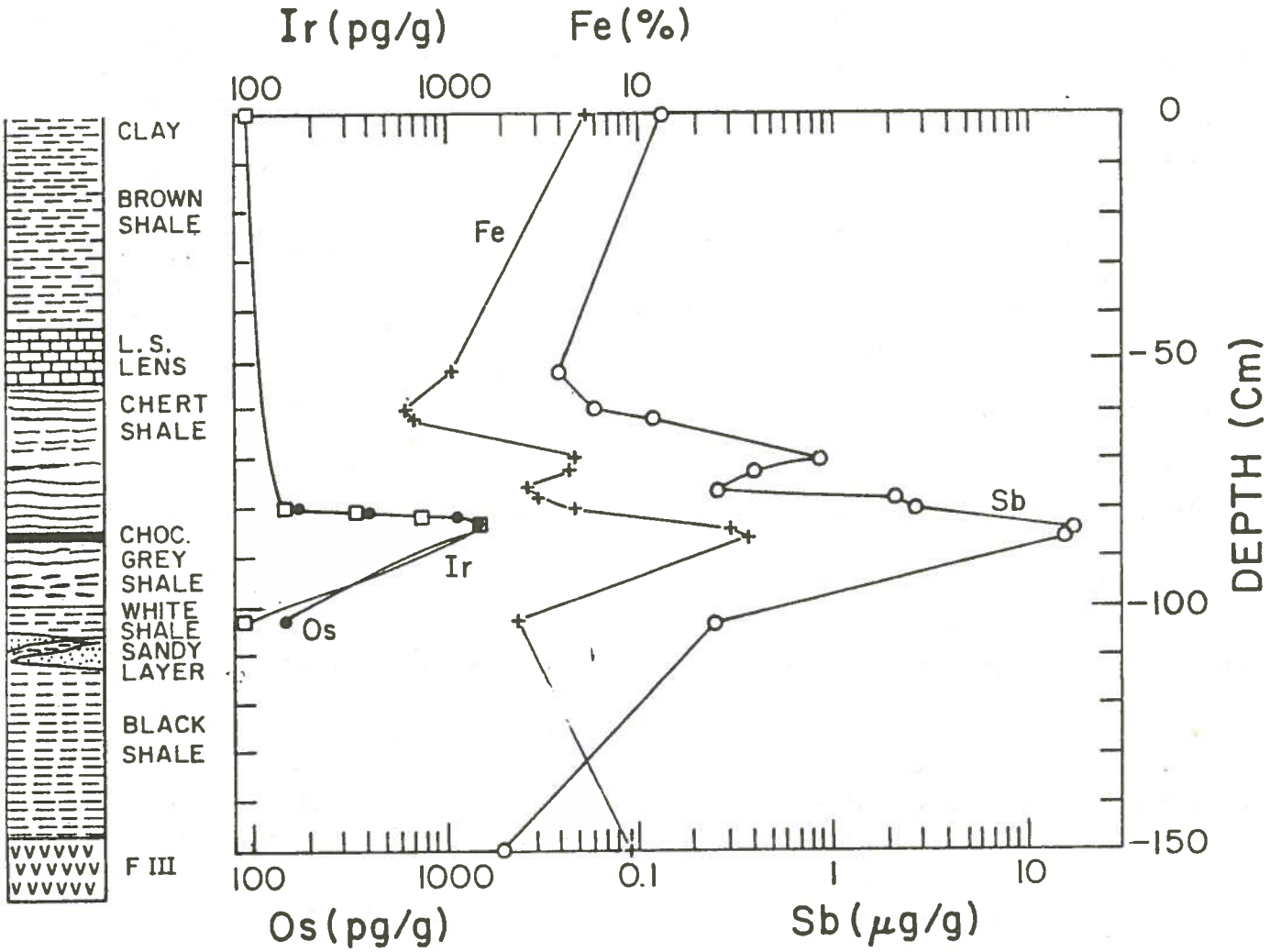
The Deccan flood basalts have assumed great importance because of their association with K/T mass extinction. The new results obtained by our group show that KT impact did not trigger Deccan volcanism. A new K/T boundary layer within the Deccan intertrappeans has been identified.

Identification of K/T boundary layer within Deccan intertrappean sediments at Anjar : The Discovery of anomalously high iridium at the Cretaceous-Tertiary boundary (KTB) by the Berkeley group of Alvarez and its global occurrence in many marine and continental sections has started an intense debate about its origin and its role in mass extinction. A large number of evidences, such as high iridium concentration, presence of shocked quartz, silicate spherules, spinels and tektites in KTB sediments, and identification of an impact crater at Chicxulub favour a bolide impact at the KTB. On the other hand, the eruption of large scale Deccan volcanism in central India at about the same time, has given rise to alternative scenarios. For example, it has been proposed that the mantle material, rich in Ir, can emanate during volcanic episodes, resulting in the iridium rich KTB layer and a continuous stress on life on the Earth. Discovery of iridium rich vapors in Hawaiian volcanoes has further strengthened this hypothesis. To explain all these features, combined models involving both impact and volcanism have been put forth. It has been proposed that large impacts induce volcanism on Earth by pressure relief melting in the asthenosphere, as is believed to have occurred on the Moon. Similar periodicities in major geologic events and of energetic impact craters on Earth has given rise to the hypothesis that the impacts can influence global tectonic cycles. Some arguments have been put forth that impact and volcanic events at the KTB are two independent events, occurring by chance at about the same time. Furthermore, because of the association of the KTB layer with mass extinction, there has been much debate as to whether the observed gradual or step wise extinction and extended iridium profile can be caused by asteroidal or cometary impacts.

It was realized that important clues to the actual cause of KTB events may lie in the characterization of a KTB layer within Deccan volcanic regime. Therefore a search for an iridium rich layer has been made in the past at several locations. Now we have identified the iridium rich

KTB layer in Anjar intertrappeans and characterized it chemically and geologically.

Mesozoic sediments and Deccan traps are extensively exposed in Kutch region of western India. The heavily folded Anjar trap sequence consists of seven basalt flows with five intertrappean sediment beds and one red bole horizon. A variety of observations suggest that this trap sequence was emplaced during the uppermost Cretaceous. Presence of Sauropod Dinosaur bones, egg shell fragments, and other Upper Cretaceous fossils in the second and third (IT-II and IT-III) intertrappeans have been documented by Geological Survey of India. The IT-III consists of the uppermost horizon containing *in situ* dinosaur fossils. Two of the traps, FIII and FIV have been dated in our laboratory by ^{39}Ar - ^{40}Ar method to be 65.5±0.7 and 65.4±0.7 million years, coincident with the 65 million year KT boundary. The intertrappean sediments IT-III consist of a 9m thick sequence of gypseous clays, splintery black-grey shales, cherty limestone and bedded chert. The grey and black shale in



3.7 Depth profile of iridium and some other diagnostic elements in Anjar intertrappean section showing anomalously high concentrations of Ir, Os and chalcophile elements representing K/T boundary.

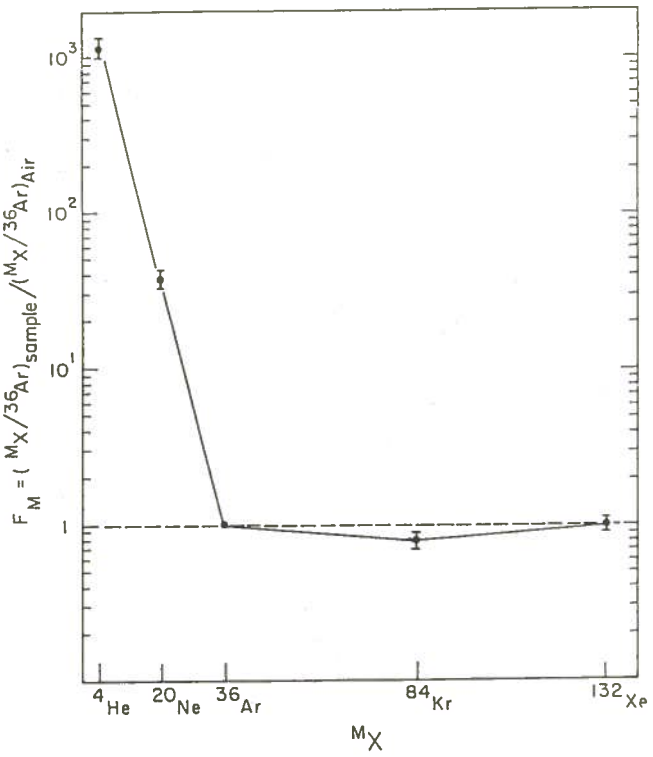
the third intertrappean bed contains three closely spaced, ≤ 1 cm thick, hard compacted chocolate colored layers. Several samples from this trap-intertrap sequence were collected and analysed for about 30 elements using atomic absorption spectrometry and instrumental and radiochemical neutron activation analysis. In this way, concentration of several siderophiles (Fe, Co, Cr, Mn, Ni, Ir, Os), chalcophiles (Sb, Se, As, Zn, Ag, Cu) and lithophiles (Al, Mg, Na, K, Ca, Ba, Sc, Hf, Th) and 9 REE (La, Ce, Nd, Sm, Eu, Gd, Tb, Yb, Lu) could be determined. Radiochemical technique for the measurements of silver at the ultra trace levels (10^{-9} to 10^{-12} g/g) was developed for this purpose.

Based on the chemical characteristics, we have identified the iridium rich Cretaceous-Tertiary boundary layer within the third intertrappean sediment bed at Anjar as the KTB layer. It has concentration of Ir (1271 pg/g) and Os (1414 pg/g), about 20 times higher than in the adjacent sediments and the underlying basalt. High concentration of Ir and Os and other siderophiles is accompanied by enrichment of chalcophiles like Se, Sb, Ag, As and Zn and depletion of lithophiles like Sc, Hf and Al compared to the underlying basalt. Some of these characteristics are similar to other continental and marine KTB sections. The Os/Ir ~1.1, close to the meteoritic value and other chemical and stratigraphic criteria indicate that it is the fallout ejecta layer, resulting from the bolide impact at the KT boundary (Fig. 3.7).

Many hypotheses including asteroidal and cometary impacts, Deccan volcanism, impact induced volcanism and coincidental impact and volcanism have been put forth to explain the observed enhancement of iridium and mass extinction at the K/T boundary (KTB). The identification of K/T boundary layer within the Deccan intertrappean sediments at Anjar, about half way between Flow III and Flow IV provides new constraints on some of these hypotheses. The chemical characteristics of this layer and other chemical and stratigraphic criteria indicate that it is the ejecta fallout layer, resulting from a bolide impact at the KT boundary. Absence of enrichment of Ir and other platinum group elements in several other intertrappean sediments rule out a significant volcanic contribution of iridium. Presence of three basalt flows below this layer implies that the volcanism was already active when this layer was deposited and impact of the KT bolide did not trigger Deccan volcanism.

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

Noble gases in Muong Nong Tektite : Tektites and impactites are natural glasses formed in a hypervelocity impact by an extraterrestrial object. Depending on the impact energy the glass formed can be the irregular shaped impactites, strewn over a small area (as expected in a low energy impact) or regular shaped tektites strewn over a large area (as expected in a high energy impact) . Muong Nong (MN) tektites are blocky in shape and can be classified between normal tektites and impactites. It has been observed that volatile and atmophile elements are, in general, enriched in impactites as compared to tektites. Volatiles like halogens, Zn and Cs have been found to be also enriched in MN tektites as compared to normal tektites. In order to see how noble gases behave in MN tektites we have analysed noble gases in two samples of these tektites. The isotopic composition of Ne, Ar, Kr and Xe expected for the radiogenic isotopes are air- like.The excess ^{40}Ar gives K-Ar age of 4.5 Ma, while the true age of MN tektites is 0.7 Ma. The



3.8 Noble gas fractionation pattern for Muong Nong tektite. While Ar, Kr and Xe are in atmospheric proportions, a clear excess of He and Ne is indicated in the sample.

elemental ratios, shown as a plot of fractionation factors (Fig 3.8) indicates enrichment of He and Ne but normal air like ratios for other gases. The abundances of noble gases in MN tektites are more than in normal tektites and are closer to impactites, as observed for other volatiles. Enrichment of Ne has been observed previously by other workers in all natural glasses, but there is no report of He enrichment. The excess He cannot be due to *in situ* decay of U, Th and has to be due to diffusion of He from atmosphere into the glass similar to the case of Ne. The higher than true K-Ar age is due to incomplete resetting of K-Ar clock during the impact. This partial retention of gases could also explain the excess Kr, Xe in MN tektites as compared to normal tektites. These results indicate that MN tektites were formed in a low energy impact event .

(S.V.S. Murty)

Geochronological Frame Work of the Indian Lithosphere

The two prominent geological features of the Indian lithosphere are Himalayas and Deccan flood basalts. Our group has taken up the problem of dating the evolutionary history of Himalayas. We have analysed samples of the Shyok and Indus suture zones in the Ladakh Himalayas to decipher the relative timing of these two sutures.

Collision tectonics and Geochronology Frame-work : In Ladakh sector of the northwest Himalaya, a nearly complete record of magmatism, sedimentation and deformation is preserved which is ideal for the study of crustal growth and collision tectonics between the Indian and Eurasian plates. The Ladakh batholith and associated igneous rocks and volcanics are bound by two suture zones viz, the Indus suture zone and Shyok-Nubra suture zone. The age sequence of these suture zones is important for understanding the way Indian plate collided with the Asian plate. Inspite of careful field and petrological studies the relative timings of these collision zones is still debated. Hence, a detailed geochronological study of various volcanics associated with these zones has been recently initiated in our laboratory. To begin with, six whole rock samples from the northern collision zone - (Shyok-Nubra suture zone) - and two from the Indus suture zone in south are dated by ^{40}Ar - ^{39}Ar dating method. Most of the samples give age spectrum indicative of partial loss of argon due to thermal events, i.e. post collisional events. From

the age spectra, we conclude that the Indus suture formed around 80 Ma and is older than the northern - Shyok suture - which might be placed around 39 Ma. The terminal thermal events that caused partial loss of ^{40}Ar from these rocks vary from 8-14 to 28-30 Ma.

(T.R.Venkatesan, K. Pande, J.R.Trivedi)

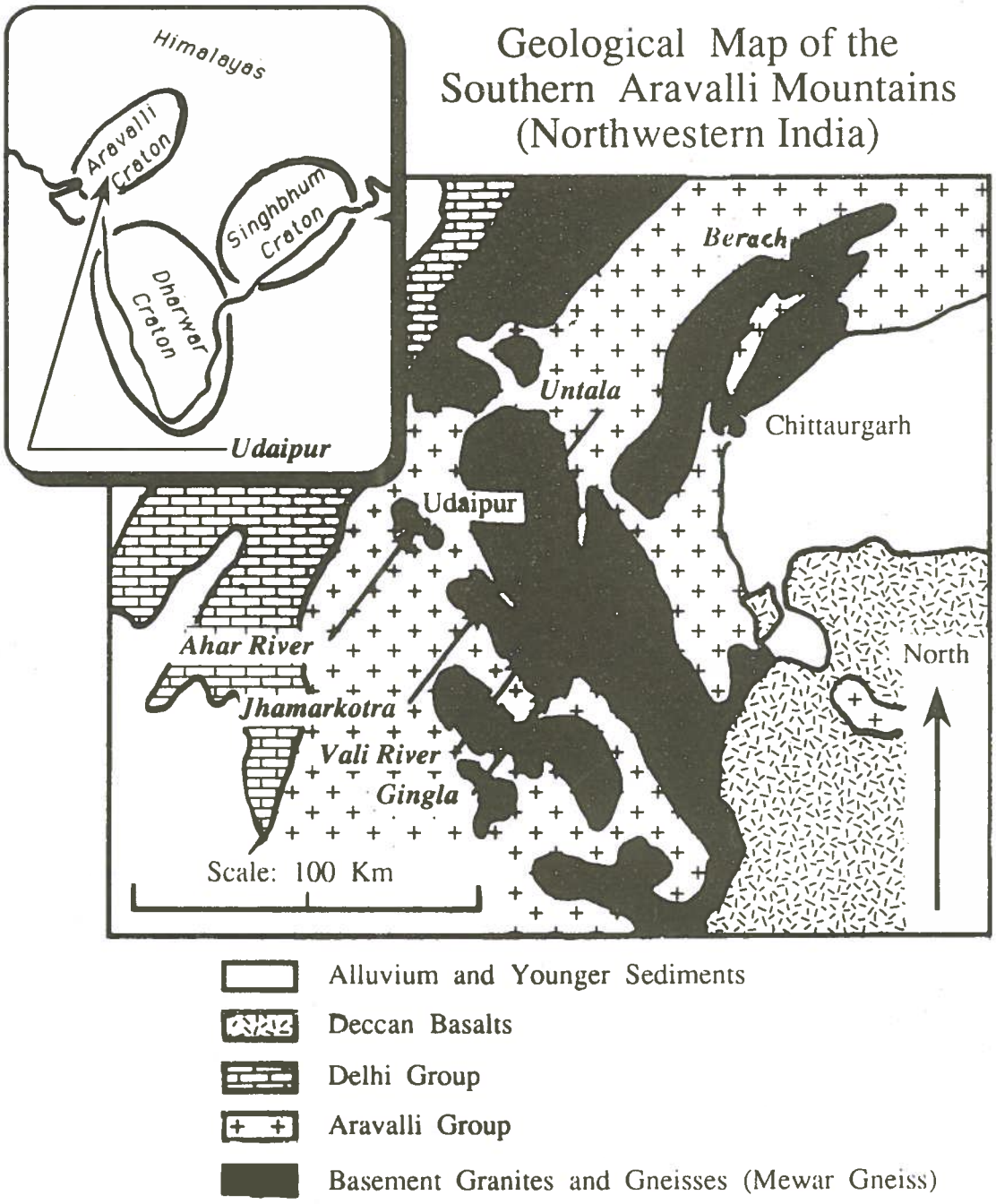
Evolution of Indian lithosphere during the Precambrian era : Three early precambrian continental nuclei have been identified within the Indian subcontinent: the Dharwar, Singhbhum and Aravalli protocontinents. However, the lack of exact geochronological data has obscured our understanding of the evolution of these terrains. The time of stabilization of these continental nuclei are not yet established nor is it known when these three zones coalesced to form the greater Indian shield. One of the major problems of dating old crustal component using well known isotopic dating techniques (e.g. Rb-Sr, Sm-Nd) is the fact that these isotopic systematics were perturbed by geological events that took place since the time of formation of the crustal rocks. Attempts to obtain precise data for emplacement of the igneous protolith of the Aravalli and Singhbhum cratons by Rb-Sr and Sm-Nd methods has met only with limited success. However, the mineral zircon, which is rich in uranium is extremely resistant to geologic perturbations and it is well known that U-Pb dating of zircon, present in the old crustal rocks, can provide reliable information on the time of their formation. Several approaches have been used for finding age of a single zircon. The most appealing one is the ion-probe technique which allows one to choose small domains (< 20 μm) within single zircon grain as opposed to isotope dilution and evaporation techniques. Last year we have accomplished $^{207}Pb/^{206}Pb$ dating of single zircon by our ion microprobe and we have now measured zircon ages from seven samples collected from the southern Aravalli Mountains (fig.3.9) to establish the age of the Aravalli Craton and the time of its stabilization. The five granite samples yield ages in the range of 2.45 to 2.56 Ga and a sample of the Mewar gneiss yielded an age of 3.28 Ga. Our data provide a consistent picture of widespread crustal generation around 2.5 Ga in this region. This result, in conjunction with field observations, indicate that the broad stabilization of the Aravalli Craton had occurred by ~2.5 Ga.

(J. N.Goswami, M. Weidenbeck, N. Sinha, M. P. Deomurari and V. G. Shah)

Presolar and Early Solar Processes

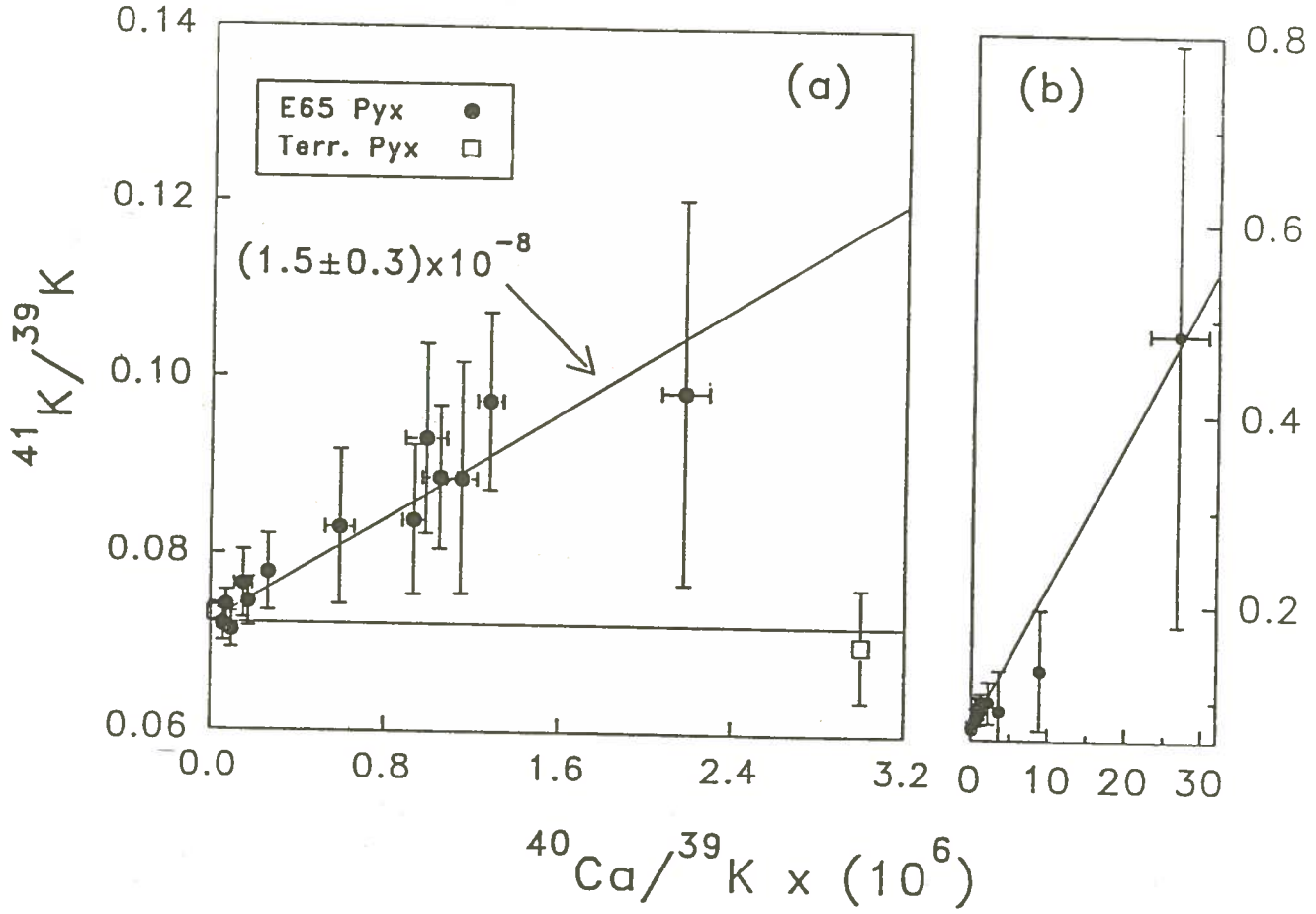
Primitive meteorites contain refractory grains that are considered to be some of the first solids to have formed in the solar system. Presence of pre-solar (interstellar) phases like diamond, silicon carbide and graphite in certain meteorites has also been established in recent years. Isotopic studies of the refractory grains and interstellar phases preserved in meteorites provide important clues towards understanding of pre-solar and early-solar processes. We have investigated both these aspects during the current year using the ion microprobe and nitrogen and noble gas mass-spectrometric techniques.

^{41}Ca in the Early Solar System: Isotopic studies of refractory phases from primitive meteorites, representing some of the first solids to form in the solar system, have established the presence of several short-lived (now-extinct) nuclides (e.g. ^{26}Al, ^{53}Mn, ^{60}Fe, ^{107}Pd and ^{129}I) with mean life $\geq$ I Ma in the early solar system. The presence of these nuclides in early solar system solids manifests



3.9 Geological Map of the Rajasthan Aravallis. The different locations from which samples were dated by the single zircon analysis by the ion microprobe are also marked.

itself through an excess in their radiogenic daughter nuclide concentrations (e.g. an excess in ^{26}Mg if ^{26}Al was present). Their presence provides important information on time scales of processes affecting the evolution of the early solar system, and in particular, constrains the time interval Δ between the cessation of nucleosynthetic input to the solar nebula and the formation of the first solar system solids. At present ^{26}Al, with a mean life of 1 Ma, is the shortest-lived radionuclide whose presence in the early solar system has been conclusively established. This observation suggests that the value of Δ could at most be ten million years. Obviously, this time interval can be better constrained through the observation of a radionuclide with a shorter mean life. Search for other short-lived nuclides (e.g. ^{36}Cl, ^{41}Ca, ^{99}Tc etc.) have so far not yielded conclusive results. We have carried out ion microprobe studies of calcium and potassium isotopic compositions in refractory phases of the primitive carbonaceous chondrite, Efremovka, to look for possible presence of excess ^{41}K resulting from the decay of ^{41}Ca with a mean-life of ~ 0.15 Ma, much shorter than ^{26}Al. The refractory phases from the Efremovka meteorite were chosen for this study, because:



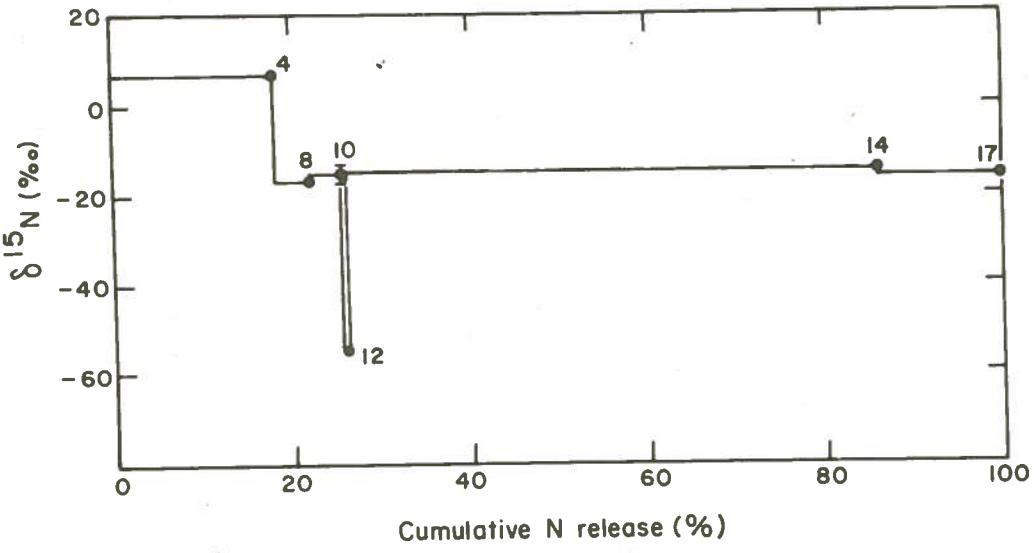
3.10 Plot of potassium isotopic ratios as a function of $^{40}Ca/^{39}K$ in refractory pyroxene (pyx) grains from the Efremovka meteorite. The horizontal line represents normal potassium isotopic ratio (0.072). The data clearly demonstrate that the excess ^{41}K in the meteorite phases correlate with ^{40}Ca indicating that this excess resulted from in situ decay of ^{41}Ca that was incorporated live into these objects at the time of their formation. The initial value of $^{41}Ca/^{40}Ca$ at this time is given by the slope of the correlation line.

i) earlier isotopic and petrographic analyses of these samples suggested no major secondary alteration of these early solar system solids and ii) these phases (e.g. pyroxene and perovskite) also have high Ca/K, making them suitable for this study.

We found evidence for excess ^{41}K in the Efremovka samples that can be attributed to *in situ* decay of ^{41}Ca in the early solar system and incorporation of *live* ^{41}Ca into the refractory phases of the Efremovka meteorite at the time of their formation. The presence of excess ^{41}K in the Efremovka samples which correlates with ^{40}Ca (fig. 3.10) constrains the time interval between cessation of nucleosynthetic input into the solar nebula and the formation of the first solar system solids to less than a million years. Such a short time interval is also consistent with the recent observation of excess ^{60}Ni [resulting from the decay of ^{60}Fe (mean life ~ 2 Ma)] in differentiated meteorites that suggests the formation of large (>>km-sized) objects in the early solar system and their subsequent melting, cooling and recrystallization within a short span of 10 Ma.

(J.N. Goswami and G. Srinivasan)

Search for interstellar diamonds in Dhajala: Interstellar diamonds have now been observed in both carbonaceous as well as ordinary chondrites, their abundance decreasing with the increasing degree of metamorphism of the parent meteorite. Since Dhajala meteorite belongs to metamorphic grade H3-4, wherein diamonds can survive, we attempted to isolate interstellar diamonds from Dhajala. We isolated a carbonaceous fraction by acid dissolution technique wherein diamonds are supposed to be concentrated, and studied its N and Xe isotopic systematics. The Xe did not show any signatures of Xe-HL, but gave a uniform isotopic composition of Xe-Q. Nitrogen also gave a uniform $\delta^{15}N = -15$ ‰ except for a sharp decrease in 1200°C fraction to -55 ‰, representing 0.3% N (Fig 3.11). Since 1200°C is the temperature



3.11 Temperature release pattern of nitrogen isotopes in the acid residue of Dhajala meteorite. Numbers indicate temperature in hundreds of °C. The sharp fall in the $\delta^{15}N$ in the 1200°C is due to release of light nitrogen from interstellar diamonds. An abundance of 7 ppb diamonds in Dhajala is derived from this result.

for the maximum release of N from diamond and the $\delta^{15}N$ signal of interstellar diamonds is - 330 ‰, we attribute this dip in $\delta^{15}N$ to be due to the presence of interstellar diamonds in Dhajala and estimate the abundance of diamonds to be 7 ppb. Earlier an upper limit of diamond abundance in Dhajala of 100 ppb has been arrived at, based on the Xe-HL component. Our limit of 7 ppb based on light nitrogen component shows that N is a much better tracer for interstellar diamonds than Xe-HL.

(S.V.S. Murty)

Origin of diamonds in ureilites : Ureilites are carbon rich achondrites and have large amounts of planetary noble gases. Most of the carbon in ureilites is in the form of diamond or graphite. Whereas graphite is mostly devoid of gases, the diamond hosts the entire noble gas inventory of the bulk meteorite. Earlier it has been suggested that ureilitic diamonds have formed *in situ*, by shock events during collision in space wherein graphite is transformed into diamond. The virtual absence of gases in graphite and the very low value of $^{40}Ar / ^{36}Ar$ in diamonds, however, argues against *in situ* shock formation process and suggest formation of diamond very early in the history of the solar system.

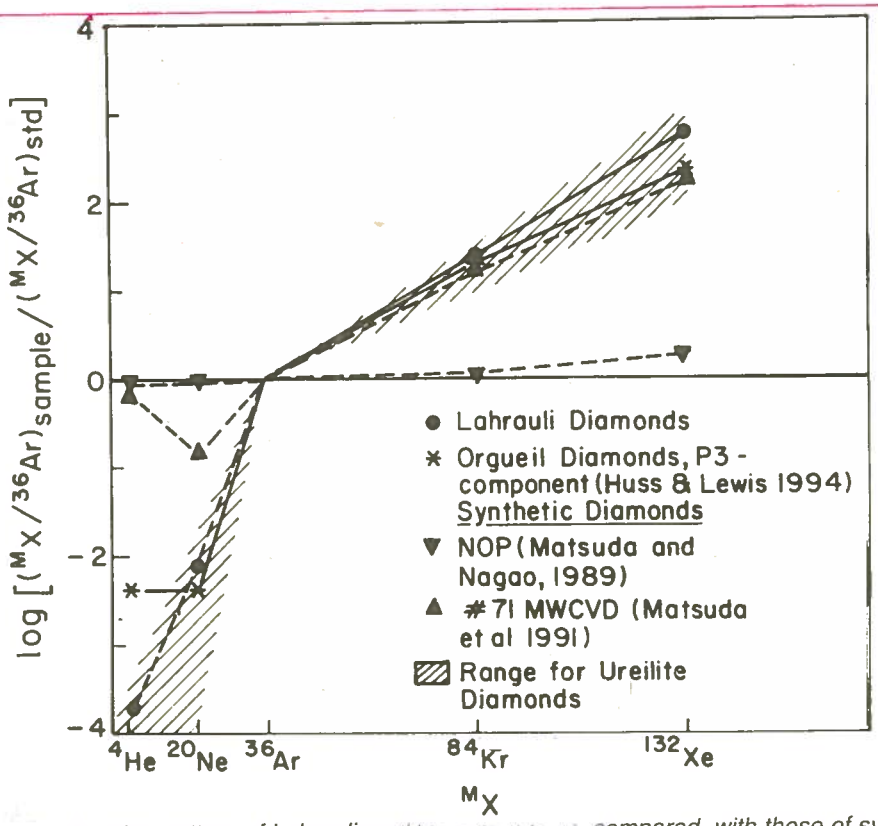
We have carried out nitrogen and noble gas studies of diamonds isolated from the Lahrauli ureilite to obtain further insight into the origin of ureilitic diamonds and also to see if they are the principal carrier of nitrogen in these meteorites. The diamond is in fact enriched in both nitrogen and noble gases compared to the bulk meteorite, the enrichment factors being 40(Ar, Kr, Xe), 400(Ne) and 70(N). The isotopic composition of all noble gases is uniform in all temperature fractions while for nitrogen the $\delta^{15}N$ drops from - 58 ‰ at 1200° C to -111 ‰ at the highest temperature. The diamond phase can nearly account for the total noble gas and nitrogen inventory of the bulk meteorite. The large enrichment factor for Ne compared to other noble gases is most probably due to the presence of a minor amount of amorphous carbon phase wherein such Ne enrichments are observed.

Elemental fractionation factors, defined as $F_m = (^{M}X / ^{36}Ar)$ sample/ $(^{M}X / ^{36}Ar)$ solar, have been plotted in Fig. 3.12 and compared with the values for synthetic diamonds. The clear match of the ureilitic diamond patterns with those of diamonds formed by gas phase condensation, and distinct differences with shock produced diamonds, suggest that ureilite diamonds most probably originated as direct condensation product from the solar nebula.

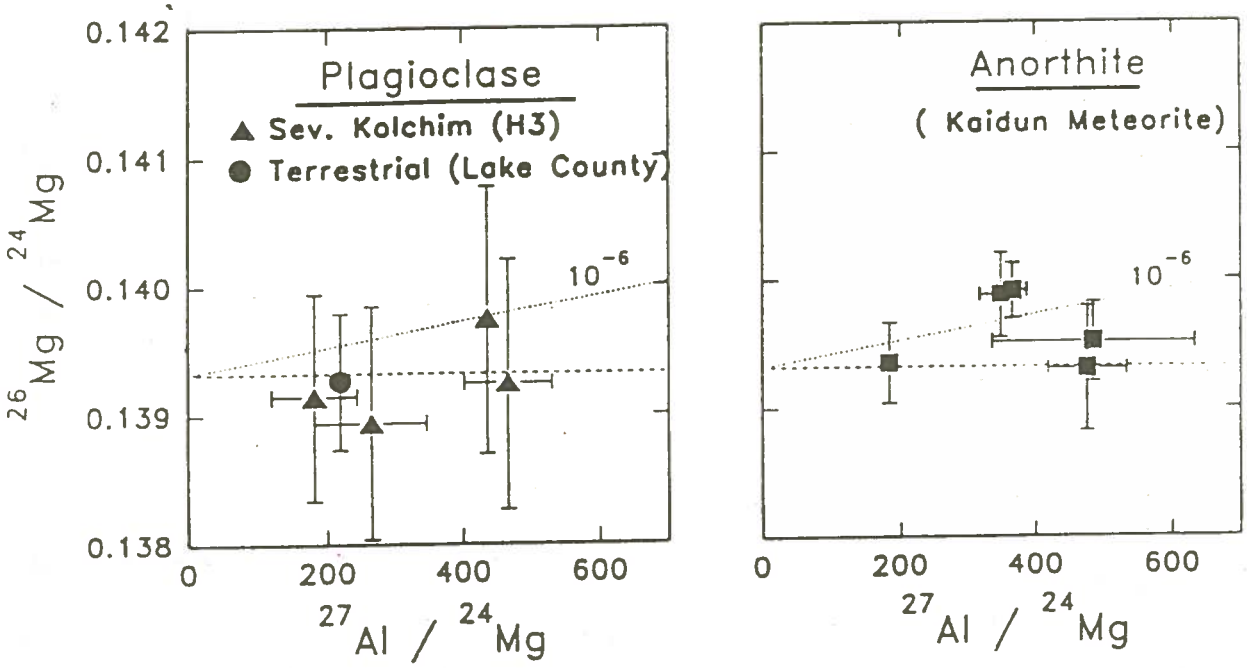
Another clear evidence for condensation origin comes from $\delta^{15}N$ of Lahrauli diamonds. The C/N=1290 and $\delta^{15}N$ = - 92 ‰ for the diamonds in Lahrauli, whose bulk $\delta^{15}N$ = - 72 ‰, match with the values for diamonds and HF/HCl residues from other ureilites whose bulk $\delta^{15}N$ is upto + 32 ‰. If diamonds in ureilites are *in situ* produced by shock, then $\delta^{15}N$ signature is expected to reflect that of the bulk meteorite. The uniform light $\delta^{15}N$ signature in diamonds from ureilites with different bulk $\delta^{15}N$ signatures is only possible if diamonds formed from the nebula in a region where a light nitrogen reservoir existed. In such a model, diamonds have to be incorporated into the ureilites at a later stage.

(S.V.S. Murty)

^{26}Al as a heat source for planetesimal melting: It is now well established that melting and differentiation of parent bodies of certain meteorites (achondrite, stony-iron, iron) took place rather early in the history of the solar system, perhaps within less than 10 Ma from the time of isolation



3.12 The noble gas fractionation pattern of Lahrauli ureilite diamonds is compared with those of synthetic diamonds (shock produced and vapour deposition type). A clear match of the ureilite diamonds with the vapour produced diamonds and a clear contrast with shock produced diamonds, strongly suggest that ureilitic diamonds are direct condensates from the nebula.



3.13 Al-Mg isotopic composition in plagioclase and anorthites from Severnyi Kolchin and Kaidun meteorites. The normal magnesium composition is shown by the horizontal line and the expected evolution for an initial $^{26}Al/^{27}Al$ of 10^{-6} is also shown.

of the solar nebula. The most plausible heat source for the early melting and differentiation of the meteorite parent bodies (planetesimals) could be the now extinct short-lived radionuclides, particularly ^{26}Al (half-life = $7x10^5$ years) and ^{60}Fe (half-life ~1.5 Ma). Presence of ^{26}Al at the time of formation of Ca-Al-rich refractory inclusions (CAIs), considered to be some of the first solids to have formed in the solar system, is well established. However, its presence in samples of differentiated meteorites or in basaltic objects found in primitive chondrites has not been established conclusively. Presence of ^{26}Al in such objects can uniquely prove it to be the primary heat source for early melting of parent bodies of achondrites as well as thermal differentiation of chondritic parent bodies. The expected value for initial ^{26}Al / ^{27}Al in planetesimals that can induce melting of silicates is ~$5x10^{-6}$ for objects ≥30 km in size. The expected value for initial ^{26}Al / ^{27}Al in differentiated objects is therefore expected to be >10^{-6}, if cooling rates were fast enough to allow closure of the Mg-Al isotopic system in recrystallized silicates within a few Ma. We have looked for possible ^{26}Mg isotopic anomaly, resulting from the decay of ^{26}Al, in igneous objects found in the unequilibrated chondrites Raguli and Severnyi Kolchin and in samples from the unique meteorite Kaidun. Our results (fig. 3.13) suggest normal Mg-isotopic composition for all the analysed phases, within the limits of our experimental uncertainty. A couple of anorthite grains from Kaidun suggest a small excess. However, there exists a possibility that these anorthites are CAI fragments and are not part of any igneous lithology. Evidence for planetary-scale presence of ^{26}Al in the early solar system still remains elusive.

(J.N. Goswami and S. Sahijpal)

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THEORETICAL PHYSICS

The research activities of the Theoretical Physics Area can be broadly divided into Macroscopic and Microscopic physics. The research programmes in Astrophysics, Meteorology, Climate Studies and Plasma Physics belong to Macroscopic Physics whereas research in Atomic and Molecular Physics, Foundations of Classical and Quantum Mechanics, Nuclear Physics and Particle Physics belong to the domain of Microscopic Physics. However, the newly emerging discipline of Astro-Particle Physics has both the aspects of Micro- and Macro-physics. The study of Classical and Quantum Chaos should form a bridge between Micro- and Macro-physics in certain domains of applicability. Following are some of the highlights of the work done in the past year.

The charged particle trajectories in a magnetic field having a strong toroidal component around a strongly gravitating body were found to give a natural explanation for the jets associated with high energy sources in the sky such as Active Galactic Nuclei (AGN) and Quasars.

The presence of dust in space around planets as well as in inter-stellar environment provides strong motivation to study the dusty plasmas where dust is charged. Various modes of waves in such plasmas have been studied in the presence of magnetic fields. Starting from Boltzmann equations, fluid equations are obtained for electron, ion and dust fluid to study waves and instabilities in dusty plasmas.

In the study of charge transfer the complete framework of the impact parameter semi-classical treatment is obtained from the quantum theory of scattering involving stationary states. This clarifies the origin of travelling orbital methods used in such processes.

It is accepted that the Random Matrix Theories provide description of 'quantum chaos' in quantal systems. The fluctuations in the spectra as predicted by random matrix theories, are then used to study order- chaos transition or the change of symmetries in quantal systems such as interacting bosons used in the description of nuclei.

Using the finite temperature field theory it is shown that the quark-antiquark pair production rate grows as the square of the temperature of the quark gluon plasma.

A model of pulsar is proposed as a hybrid state consisting of a quark matter core surrounded by neutron matter. This model is based on the quark matter equation of state including effect of confinement of colour.

The analysis of high precision data of Z-parameters from LEP in the framework of left-right symmetric models for electro-weak interaction gives a parameter independent stringent limit of 813 GeV for the mass of the right-handed charged gauge boson required by the models.

Neutrino oscillations among the three generation type neutrinos were shown to resolve solar and atmospheric neutrino problems. Moreover, the hot dark matter in the Universe requires that all the neutrinos be degenerate.

The theory of supergravity predicts the spin 3/2 particle gravitino. The energy loss from stars provides a strong limit on the mass of the gravitino which is several orders better than that obtained from experiments in the laboratory.

MACROSCOPIC PHYSICS

ASTROPHYSICS

Accretion Disk in the Presence of Both Poloidal and Toroidal Field

Earlier studies pertaining to equilibrium structure of accretion disks in the presence of radial gravitational field along with poloidal components

of magnetic field in the domain of both Newtonian and general relativity backgrounds have exhibited several interesting features on the possible critical fields for having disks quite close to central compact objects. As the plasma in the disk rotates around the compact body, motion of ions and electrons in the plasma environment going around the central star would produce poloidal currents which yield magnetic field in the toroidal direction also. As a result of the generation of this toroidal field, angular momentum is exchanged between the star and the disk. It is believed that the toroidal component of the magnetic field plays an important role in the generation of jets in astrophysical objects. Thus, it is important to analyze the equilibrium structure of a thick accretion disk including the self-consistent magnetic field in the toroidal direction.

We have obtained a class of equilibrium configurations for a rotating thick magnetofluid disk around a compact object in the presence of both poloidal (externally induced) and self- consistent toroidal magnetic fields. The magnetic field topology within the disk shows twisted features increasing with the strength of the toroidal component. The pressure and density profiles have been explicitly obtained for the case of a quasi-Keplerian velocity profile for the azimuthal flow of the magnetofluid. The physically plausible pressure and density distributions (i.e. decreasing monotonically from the equatorial plane in the meridional direction) require ratio of gravitational potential energy to bulk kinetic energy of a fluid element at the inner edge to lie within the given bounds.

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

Ellipticity Variation and Reversal of Centrifugal Force in Rotating Ultra-Compact Objects

The studies for reversal of centrifugal force made so far deal with test particles orbiting outside the relativistic ultra-compact object in Schwarzschild space-time (static metric) and Kerr space-time (stationary metric). The centrifugal force reversal in Kerr space-time has been studied using locally non-rotating frames.

These studies are further extended to find the nature of centrifugal force acting on a test particle orbiting 1) outside a slowly rotating relativistic object, and 2) inside a slowly rotating relativistic object represented by an approximated solution, the Hartle-Thorne metric, for various matter distributions. In the case under consideration matter distribution is an equilibrium mixture of non-interacting, degenerate nucleons and electrons described by the Harrison-Wheeler equation of state. The influence of the centrifugal force reversal on the change of shape of the rotating object will be studied through the study of ellipticity variation.

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

Charged Particle Trajectories in a Toroidal Magnetic Field Superposed on Schwarzschild Geometry

Considering the equation of motion for a charged particle in electromagnetic fields superposed on a curved background (Schwarzschild geometry), we have shown that in the presence of toroidal magnetic fields stronger than the poloidal field, the incoming particle gets bounced off in a straight line trajectory through a region close to the polar region of the compact object sustaining the gravitational field. It is indicated that such trajectories are possibly the ones that collimate the particles into an accelerated beam forming the jet associated with high energy sources like AGNs and Quasars. This work was done in collaboration with Mr. S. Sengupta of Indian Institute of Astrophysics, Bangalore.

(A. R. Prasanna)

Large Scale Structure

A technique based on the calculation of the probability of deviation from a random distribution has been employed to study the large scale structure of the universe. Appropriate quantities have been identified to classify the observed structures (clusters of different multiplicities and voids) and a classification scheme indicating the degree of confidence in these structures has been developed.

The method has been applied to a part of the CfA catalogue corresponding to a small region of the sky. Detailed analysis has shown that even this small region contains a surprising degree of structure. Various clusters and voids have been identified with a high level of confidence.

The extension of the analysis to the whole sky is in progress. It is planned to use this technique for the study of the evolution of large scale structure with time (using results of N-body simulations) and the distribution of voids, and for comparison between observed data and the predictions of various theories of structure formation.

(Joanna Anosova, Sai Iyer and R. K. Varma)

METEOROLOGY AND CLIMATE STUDIES

In the context of climate change, a problem of great importance is understanding the causes and mechanisms of variability of monsoon and tropical circulation on the interannual and decadal timescales. A beginning was made this year in developing a global climate model for addressing this problem. A five level (vertical resolution) and 21 wave (horizontal resolution) spectral model has been developed. To this dynamical frame work, various physical processes relevant for climate change are being incorporated. This year, the important subgrid scale process of cumulus convection and heating due to it was included in the model via Kuo's parameterization scheme. Orography appropriate for 21 wave resolution was also incorporated. Inclusion of other important physical processes such as radiation and planetary boundary layer is in progress.

Growth of Monsoon Depressions

The growth and evolution of perturbations in different model generated basic flows are studied by conducting idealized experiments with a high resolution global spectral model. Our objective in this is to understand how changes in mean monsoonal flows affect monsoon cyclogenesis. In a global spectral model with five vertical levels and a horizontal resolution of 35 waves, basic flows corresponding to weak, normal and strong monsoon conditions were generated by driving the model with realistic heating distributions appropriate for these situations. The three dimensional heating distributions used here are derived from observations. It is found that the horizontal and vertical structure of the model generated flows for the three different cases are in good agreement with those of observed flows. According to theory, regions of instability in a horizontally and vertically sheared flow are those where the gradient of absolute potential vorticity vanishes. In view of this, we have constructed fields of gradient of absolute potential vorticity from the model generated flows. Using these maps of instability regions it is planned to study the evolution of perturbations superposed on the basic flows.

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

Climate Modelling

Work on the development of a global climate model has been continued. The model uses the

spectral method for solving the full set of nonlinear coupled PDE's governing atmospheric motions and the semi-implicit time scheme for prediction. A vertical resolution of five levels and a horizontal resolution of 21 waves with rhomboidal truncation are used. Orography appropriate for 21 waves has already been incorporated. We have now incorporated the modified convective parameterization scheme of Kuo in the model to treat the important process of heating by cumulus convection in the atmosphere which is a subgrid scale phenomenon.Work is in progress to include other important physical processes such as radiation, planetary boundary layer and vertical diffusion.

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

PLASMA PHYSICS

Plasma Irregularities in Auroral Ionospheric Plasma

This is the continuation of the work reported last year on a mechanism for the generation of plasma irregularities in the auroral ionospheric plasma. It has been pointed out that the background electric field was not considered earlier and it is highly desirable that this electric field be included in the model exclusively to examine its effects on the generation mechanism of the irregularities.

In the present model, the electric field is included and a few very interesting results have been found. For example, the usual two-stream type instabilities are not generated in the absence of $\eta(=L_N/L_T)$ and Q (heat source) even when $k \cdot v_d \neq 0$ because the electric field is in the direction opposite to that of the background density gradient. For $\eta \neq 0$, the instabilities can be generated with large growth rate both for $k \cdot v_d \neq 0$ and $k \cdot v_d = 0$, where v_d is the electric drift velocity, and therefore are capable of explaining the radar data observed in all directions. It is associated with phase velocity larger than the ion-acoustic velocity and may be important for some observed irregularities with unusual spectral signature identified as type-4 radar aurora. This work was carried out in collaboration with A. G. Sheikh of C. U. Shah College, Ahmedabad.

(A. C. Das)

Theory of Low-Frequency Waves in Magnetized Dusty Plasmas

A systematic analysis of the low-frequency modes such as the hydromagnetic and the acoustic waves in a magnetized dusty plasma containing electrons, ions and charged dust grains has been completed. For this purpose, we develop a MHD model by starting with the three-fluid equations and the Maxwell equations. Because of the low-frequency, we neglect electron inertia as well as the displacement current (in Ampere's Law), and assume quasi-neutrality between the three components. By eliminating the electron variables and the electric field from the equations, we thereby derive a set of two-fluid MHD-like governing equations for the ions and the dust particles. The relevant momentum conservation equations contain additional new terms giving rise to an effective inertial resistivity (even in the absence of collisions) which lead to waves wherein the electron and the ion number density perturbations are not frozen to the magnetic field lines.

The general dispersion relation of the governing equations has been obtained and analyzed for the existence of various modes. It is shown that normal modes exist in two widely separated frequency regimes. For wave frequencies much

smaller than the gyro-frequencies of all the species, we obtain hydromagnetic and acoustic waves that are the generalization of the usual corresponding modes in a two-component plasma. On the other hand, for frequencies much larger than the dust gyro-frequency but much smaller than the ion- and the electron gyro-frequency, we recover the so-called "Dust-Magnetoacoustic Waves" presented in this report last year. These waves are shown to have qualitatively different dependences on the equilibrium parameters such as the number density, the magnetic field and the temperature when compared with the usual magneto-acoustic waves even in a three-component plasma. In the two-component limit, the new modes degenerate into usual type of magnetoacoustic modes. Waves arising because of the ion- as well as the dust-inertial effects have been classified and analysed separately.

(N. N. Rao)

O-Mode Conversion into Upper-Hybrid and Bernstein Modes in Ionospheric Modification Experiments

Recent experiments on the artificial modification of the Earth's ionospheric F-region plasma by means of intense electromagnetic waves (with frequencies near the harmonics of electron gyro-frequency) launched from ground based transmitters has shown rich structure in the Stimulated Electromagnetic Emission (SEE) spectra from the ionosphere. The present theoretical understanding of the various SEE spectral features requires the existence of electrostatic modes propagating perpendicular to the ambient magnetic field in the upper-hybrid resonance region. In particular, high-frequency waves such as the upper-hybrid and the electrostatic Bernstein modes have been invoked.

We have suggested a mechanism for the excitation of the electrostatic waves by means of the resonant mode conversion of the incident pump O-mode electromagnetic wave. The coupling between the relevant modes and the consequent conversion process is made possible by means of small, but non-zero, wavenumber parallel to the magnetic field. Our results show that for typical values of the parameters relevant to the recent experiments at Tromsö (Norway), O-mode resonant conversion into upper-hybrid waves is possible for the ambient density gradient scale-lengths. However, resonant excitation of the electrostatic Bernstein modes is found to be possible only in the double-resonance region where the upper-hybrid frequency and the Bernstein frequency overlap. For the non-degenerate case when the two frequencies are distinct, the conversion efficiency is practically negligible for the Tromsö parameters.

(N. N. Rao)

Instabilities of Electron Plasma Waves in Unmagnetized Dusty Plasmas

Nonlinear interaction between a large amplitude electron plasma wave and low-frequency perturbations in dusty plasmas has been investigated. A nonlinear dispersion relation appropriate for three-wave decay interaction as well as modulational and filamentation instabilities is obtained. Analytical expressions for the growth rates and the thresholds are presented. A set of dynamical equations for describing the long term behaviour of the modulationally unstable electron plasma waves in plasmas with fixed charged dust particles has also been obtained. Possible applications of our analysis to noctilucent clouds on the night sky of the Earth's polar regions during summer seasons has been pointed out. This work was carried out in collaboration with P. K. Shukla and G. Feix.

(N. N. Rao)

Excitation of Magnetic Fluctuations by Intense Electron- Cyclotron Waves

At present, several research groups are using intense short pulse electromagnetic waves in the electron-cyclotron harmonic frequency regimes for the ionospheric modification experiments. There are also proposals to use such waves in plasma based particle acceleration schemes. Since the short pulses have fast rise time, the ions because of their large mass would not participate in the plasma dynamics. In such cases, the external modulation of the incident pump high-frequency electromagnetic wave can give rise to magnetic perturbations whose frequencies are much smaller than the electron gyro-frequency but larger than the ion plasma and gyro frequencies. By employing the electron magnetohydrodynamic equations, we derive the relevant mode coupled equations for a magnetized plasma and analyse them for possible instabilities. In particular, it is found that the modulational instability can set in on a time scale much shorter than the ion plasma and gyro periods. Accordingly, in the initial stages immediately after the cyclotron pump switch-on, two symmetrical side-bands accompanied with non-resonant density and magnetic perturbations would appear. Such side bands have been observed in the recent ionospheric modification experiments. This work was carried out in collaboration with P. K. Shukla and R. Bingham.

(N. N. Rao)

Fluid Equations for Dusty Plasmas

Starting from the Boltzmann equations for electrons, ions and the dust component with appropriate source and sink terms, fluid equations are obtained for electron, ion and dust fluids in terms of which one can study the dynamics of dusty plasmas. The role of the dust charging term is very important as it distinguishes a dusty plasma from merely a multi-component plasma. An appropriate dust charging equation has thus been formulated. These equations are being used to study various low frequency dust plasma processes, waves and instabilities.

(R. K. Varma)

MICROSCOPIC PHYSICS

ATOMIC AND MOLECULAR PHYSICS

Charge Transfer

We have presented an overview of the present status of perturbative approaches to charge transfer in energetic ion-atom collisions. In this review, a discussion of three-body collisions for short-range as well as for long-range Coulomb interactions are given. Some fundamental problems of perturbation theory, including convergence properties of various Born expansions for three-body rearrangement collisions, are also addressed. In theoretical studies of charge exchange in energetic ion-atom collisions, the semiclassical impact parameter treatment (IPT) has been frequently employed since the early years of quantum mechanics. Several derivations of the IPT have been given in the literature but we think none of them is fully satisfactory. We have given a more straightforward and complete derivation of the framework of the IPT starting from the Schrödinger equations of the stationary state scattering theory. This derivation shows how the stationary state scattering wave functions are transformed into the semiclassical wave functions in which the variation of the internuclear distance can be described classically in terms of the impact parameter, the constant relative velocity and a parameter called time. This derivation also clarifies the origin of the

travelling orbital introduced long ago by Bates and others in order to satisfy the requirement of translational invariance. A critical assessment of various theoretical models is also presented by pointing out their advantages and shortcomings, and in some cases, by clarifying misunderstandings. The boundary-corrected perturbation formalism and its applications are discussed in some detail. Related distorted wave models and various multiple scattering approaches including the continuum distorted wave models are also discussed. The high-energy behaviour of charge transfer cross section is reviewed. A number of illustrative comparisons between theory and experiment are presented. This review is completed in collaboration with J. Eichler.

(D. P. Dewangan)

Excited-State to Excited-State Transitions of Hydrogen-like Ions

We have continued our study of collisions of charged particles with hydrogen-like ions in their excited states. As already reported, we have derived a new one-dimensional integral representation of the Coulomb-Glauber amplitude for arbitrary nlm transitions. This year we have paid considerable attention to the calculations of the cross sections and rate coefficients for excited-state to excited-state transitions of HeII and CVI by electron-impact. We have mainly concentrated on transitions among initial and final levels for which the principal quantum numbers are $n \leq 8$. It is worth mentioning here that this study involves a very large number of transitions since there are n^2 levels (excluding spin quantum numbers) in a principal shell n. The cross sections and rate coefficients are needed in the context of astrophysical applications. This work was done in collaboration with D. P. Sural.

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

CLASSICAL AND QUANTUM MECHANICS

Learning and Prediction of Orbits of Logistic Map by Multi-Layered Perceptrons

Multi-layered perceptrons (MLP) — a typical feed-forward neural network, with error-back propagation algorithm as a learning rule have been shown to be capable of learning and generalising from examples the rules underlying complex data patterns. For instance, given a data set $[x_i, f (x_i), i = 1, ..., N]$ of length N where f(x) is an unknown nonlinear function, an appropriately architectured network will be able to create its own internal representation of the function by learning to reproduce $f (x_i)$ for each x_i. It is our aim to apply the technique of neural networks and other known methods of time series analysis to study real data. We have, as a test case, trained a network on a simple non-linear map called the logistic map $f (x_t) \equiv x_{t+1} = 4 \lambda x_t (1 - x_t)$. In the range $x \varepsilon [0.0, 1.0]$, the map exhibits transition from order to deterministic chaos for increasing values of the parameter λ in the range [0.25, 1.0].

We have been able to train a neural network comprising of one input, five hidden and one output neurons to learn this complex dynamic behavior of the map. We have chosen tan- hyperbolic function as the transfer function.

It may be noted here that the approximate nature of the network in representing the map produces small errors in each iteration. Because of the growing sensitivity of the map due to onset of chaos in the range $0.892864... \leq \lambda \leq 1.0$, the

trajectories produced by the map and the neural network start deviating appreciably after a few iterations. For $\lambda = 0.91$, the two trajectories match upto 12-15 iterated points, at $\lambda = 0.95$ it reduces to less than 10 and at $\lambda = 1.0$, full blown chaos, it is only a few points. However, the plots of $(x_{t+k} \text{vs.} x_t)$, for a small integer k, show the 2^{k-1} humps characteristic of the map implying that the network has in fact learnt the map.

In order to improve the predictive performance of the network in the chaotic parameter regime, i.e. $0.9 \leq \lambda \leq 1.0$, we are now implementing the time-delay neural networks (TDNN) which should be a better architecture for time series data.

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

Topological Manifestations in Classical Mechanics : Discrete Allowed and Forbidden States of Motion

Consequences of the topology of the configuration space of a Hamiltonian dynamical system are considered for a coherent system of trajectories. It is shown that when the space is multiply-connected, and therefore the action integral is multi-valued, the allowed states of motion (labelled by the initial data) are constrained to a discrete set by the requirement that the action be single valued. One thus obtains a quantum-like discretization of allowed states of motion even in classical mechanics. Such discrete "allowed" and "forbidden" states have indeed been observed in the classical mechanical system of charged particles in a magnetic field. The relationship of this formalism with a Schrödinger-like formalism for the latter problem given earlier is discussed.

(R. K. Varma)

Double Slit in Classical and Quantum Mechanics

The motion of particles across a double slit is considered in classical mechanics. It is argued that because of the multiply-connected nature of the space induced by the double slit, the momentum vector field $\vec{p}$ is double valued; so also is the Hamilton principal function S, a solution of the Hamilton Jacobi equation. dS is, therefore, not a perfect differential since not all paths are equivalent. dS can be made a perfect differential in an extended space obtained by attaching to the $\vec{x}$-space a U(1) fibre bundle. It is shown that by imposing this as a physical requirement, one obtains a discrete set of allowed momentum values which are characteristic of quantum interference phenomena for material particles. Indeed, by making appropriate identification for $\hbar$ the de Broglie relation for the allowed momentum directions follows. Quantum interference effects thus appear to be a consequence of the topology of the configuration space.

(R. K. Varma)

Planetary and Satellite Orbits as a "Quantization" of Specific Angular Momentum

Attempts have been made over the past decades to explain the origin of the discrete orbits of planets and their satellites. The Titius-Bodes law represents an attempt to accommodate planetary distances in a purely empirical relationship. Similar kind of relationship can be written down for the distances of satellites from the parent bodies.

However, a very interesting physically significant relationship emerges for both planets and the families of minor satellites, if one examines their specific angular momenta (that is, angular mo-

mentum per unit mass). They turn out to be quantized to a very good approximation: that is, integral multiples of a fixed specific angular momentum quantum which is characteristic of a family. In fact, it is found that the inner planets and outer planets belong to two different families. Similarly, satellites of Jupiter, Saturn and Uranus belong to their respective families, from this point of view. This classification is physically very significant and is likely to provide clues of the formation of solar and planetary systems through a common mechanism for both the systems.

(R. K. Varma)

On the Quantum Baker's Map and its Unusual Traces

The quantum Baker's map is the quantization of a simple classically chaotic system, and has many generic features that have been studied over the last few years. While there exists a semiclassical theory of this map, a more rigorous study of the same revealed some unexpected features which indicated that correction terms of the order of log ($\hbar$) where $\hbar$ is Planck's constant, had to be included in the periodic orbit sum. Such singular semiclassical behaviour was also found in the simplest traces of the quantum map. We studied the quantum mechanics of a Baker's map which is obtained by *reflecting* the classical map about its edges, in an effort to understand and circumvent these anomalies. This resulted in a *real* quantum map with traces that follow the usual Gutzwiller-Tabor like semiclassical formulae. We developed the relevant semiclassical periodic orbit sum for this map which is closely related to that of the usual Baker's map, with the important difference that the propagators leading to this sum have no anomalous traces. This restores the belief that the quantum Baker's map will prove to be representative of a large class of generic quantum systems with a chaotic classical limit.

(A. Lakshminarayan)

Semiclassical Theory of the Sawtooth Map

We developed the semiclassical theory of the sawtooth maps. These are piecewise linear maps on the torus which are completely chaotic in the range of parameters we studied. The cat maps are embedded in this family as a set of measure zero and show up semiclassically when, in general, the approximate semiclassical periodic orbit sum becomes exact. While the quantum cat map is highly non-generic and has given rise to speculations about the possible failure of the correspondence priniciple, we demonstrated that the slightest perturbation away from the quantum cat produced generic quantum behaviour, for example, random matrix like eigenangle nearest neighbour spacing distribution was observed. This model is useful for several purposes, including the testing of the validity of the semiclassical Green's function in the time domain.

(A. Lakshminarayan)

Classical Transport and Quantum Spectra

It has become increasingly clear that the fundamental processes of classical transport have their origins in dynamical chaos. It is thus of interest to know the role of chaos in quantum transport. There are several related issues like eigenfunction localization, conductance fluctuations and statistical properties of eigenvalues that are intimately related to classical transport properties, in a way that is being actively explored. We study the effects of classical partial barriers to

transport on statistics of spectra. We have found that in the presence of such barriers, standard Random Matrix Theory conjectures of spectral fluctuations do not apply. A more modern approach identifying a transition parameter related to classical transport properties and Planck's constant is likely to be relevant. We study such effects in very effective but simple models such as the quantum sawtooth maps, quantum multibaker maps, and coupled quartic oscillator systems.

(A. Lakshminarayan and V. B. Sheorey)

Classical and Quantum Structures in Chaotic Systems

We continue our study of eigenstates of quantized classically chaotic coupled quartic oscillator systems. We use the Bargmann transform to study the eigenstates in a *quantum Poincaré section*. This being a coherent state, the representation is ideal for viewing quantum eigenstates through classical eyes. A detailed study of classical structures in eigenstates is then possible. These are some of the first studies on fairly high energy states of a non-billiard smooth Hamiltonian system with a chaotic classical limit.

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

Classical and Quantum Structures in a Three - Dimensional Quartic Oscillator System

In our previous work we have studied a two dimensional coupled quartic oscillator system. We have identified localized eigenstates in such a chaotic quantum system using two methods. First, we have employed direct visual methods using high speed computer graphics and second, we have defined an information entropy measure for eigenstates. Such a measure exhibits sharp minima for localized states. We anticipate that for systems with more than two degrees of freedom, visual techniques might pose cognition problems for identification of localized states. For such systems the entropy measure technique is expected to be more reliable. Furthermore, classically chaotic systems with more than two degrees of freedom exhibit certain phenomena which are absent in chaotic systems with two degrees of freedom. We are studying the quantum signature of such classical behaviour.

(M. S. Santhanam and V. B. Sheorey)

Invariants for Chaotic Hamiltonian Systems

We have shown that the existence of non-zero Liapunov exponents, a characteristic of chaotic systems, implies that an invariant related to the variation giving rise to the exponent either defines a canonical transformation with zero radius of convergence or fails to be infinitely differentiable. We have applied this to quartic Hamiltonians and shown that the contours of such invariants become increasingly more convoluted whenever the system exhibits chaos.

(B. R. Sitaram)

Investigation of Singularities of Hamiltonian Systems in Complex Parameter Space

Perturbation theory is concerned with the development of suitable expansions in the perturbation parameter for the invariants of Hamiltonians which are perturbations on an unperturbed Hamiltonian. Obviously, such expansions make sense only if the invariants are analytic functions of the parameter. Numerical techniques are being developed for testing analyticity and are being applied to time dependent perturbation theory for the Henon-Heiles Hamiltonian and to a model Hamiltonian which we had developed.

(Mitaxi Mehta and B. R. Sitaram)

NUCLEAR PHYSICS

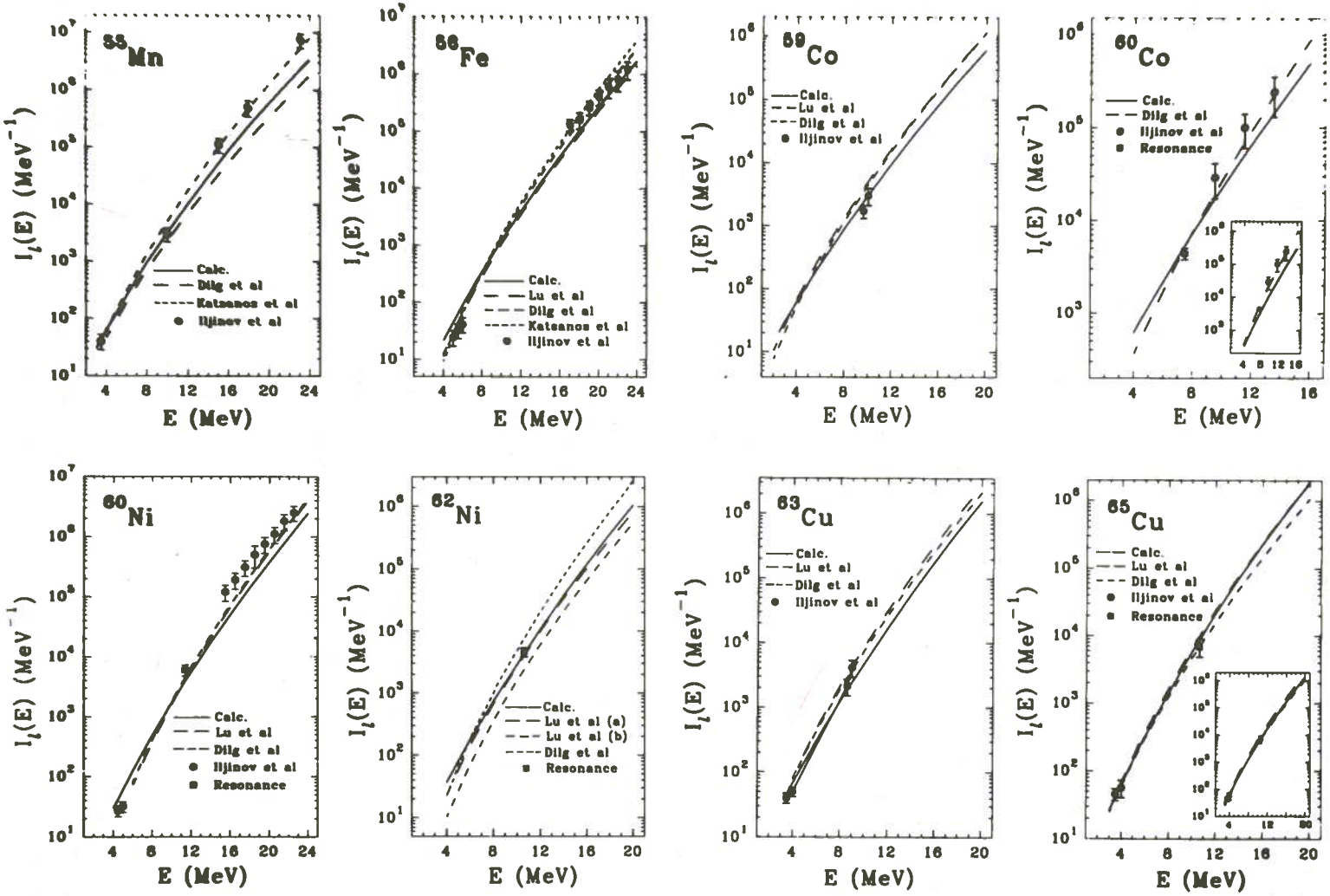
Nuclear Level Densities in Spectral Averaging Theory : First Systematic Study of fp - Shell Nuclei

A theory for nuclear level densities and spin cut-off factors is given recently by PRL scientists in collaboration with scientists at University of Rochester and Laurentian University, in the framework of spectral averaging theory where interactions are taken into account from the beginning. Using this theory first systematic study of level densities and spin cut-off factors for fp-shell nuclei are carried out this year. There are only eight fp-shell nuclei for which sufficient level density data are available and they are ^{55}Mn, ^{56}Fe, ^{59}Co, ^{60}Co, ^{60}Ni, ^{61}Ni, ^{63}Cu and ^{65}Cu (exhaustive data compilation with data from Dilg et al, Iljinov et al, Katsanos et al, Lu et al and resonance experiments is made). The calculations are performed in the $(0+2)\,\hbar\omega$ space defined by the 8 single particle orbits $\{1d_{5/2}, 2s_{1/2}, 1d_{3/2}, 1f_{7/2}, 2p_{3/2}, 1f_{5/2}, 2p_{1/2}, 1g_{9/2}\}$ for the five nuclei ^{55}Mn, ^{56}Fe, ^{59}Co, ^{60}Co, ^{60}Ni and 10 orbits $\{1d_{5/2}, 2s_{1/2}, 1d_{3/2}, 1f_{7/2}, 2p_{3/2}, 1f_{5/2}, 2p_{1/2}, 1g_{9/2}, 1g_{7/2}, 2d_{5/2}\}$ for the three nuclei ^{62}Ni, ^{63}Cu and ^{65}Cu respectively, with surface delta interaction whose strength is G MeV. The calculational details involve: (i) reference energy selection; (ii) method of fixing G value; (iii) choice of unitary orbits; (iv) state and spin cut-off density evaluation; (v) class structures; (vi) single particle energies and renormalization of sd - fp and fp - gd separations; (vii) the constraints that decide the goodness of a calculation etc. The results are shown in figure 4.1 for the total level densities $(I,(E))$ for the above nuclei and it is evident that the agreements with experimental results are excellent. Similar agreements are also obtained for the spin cut-off factors.

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

Non-Interacting Particle Strength Densities for One-Body Transition Operators

In order to calculate transition strengths for various processes (for example β decay), the first step is to construct the non interacting particle (NIP) state densities. Then the interaction effects can be easily incorporated by convoluting with a spreading bivariate Gaussian whose parameters depend on the correlations between the interaction operator and the transition operator. For one-body transition operators, with a NIP Hamiltonian, the exact expressions for the strength densities (strength weighted by the densities at the two ends) are derived by using spherical configurations. The total strength density decomposes into the partial densities defined over the so called unitary configurations (unitary orbit is a set of spherical orbits and a unitary configuration is obtained by distributing particles in unitary orbits). Propagation equations for the moments of the unitary configuration strength densities are derived. Also derived are the analytical formulas for moments of strength densities defined over the whole many particle (m) space. With unitary configuration strength densities we can carry out rapid calculation of NIP strength densities. Numerical calculations are carried out for the β^+ operator in the space of $(1d_{5/2}\ 2s_{1/2}\ 1d_{3/2}\ 1f_{7/2}\ 2p_{3/2}\ 1f_{5/2}\ 2p_{1/2})$ orbits with $m_p = 4$, $m_n = 6 \rightarrow m_p = 3$, $m_n = 7$ and verified explicitly that the unitary configuration densities are close to bivariate Gaussian in form. We also find that the densities and their various decompositions constructed by using unitary configuration densities (with bivariate Edgeworth form for them) compare



4.1 Total level density I_i (E) vs E for the eight fp-shell nucei ^{55}Mn, ^{56}Fe, ^{59}Co, ^{60}Co, ^{60}Ni, ^{60}Ni, ^{62}Ni, ^{63}Cu and ^{65}Cu calculated using spectral averaging theory and their comparison with experimental data. Total level density gives the number of levels (without regard to spin) per MeV at the excitation energy E.

very well with the exact densities. Using this NIP formalism, we are now carrying out the exercise of constructing the strength densities with spreading bivariate Gaussians due to interactions so that β decay rates at finite temperature can be calculated.

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

Scissors States in ^{163}Dy Nucleus

Two years back PRL scientists introduced a model, based on the SU(3) ⊗ U(2) symmetry and the sdg interacting boson model, for predicting the location and M1 (magnetic dipole) decay strengths for the scissors states in deformed odd mass nuclei. This year a European collaboration, for the first time claimed to have populated, using the nuclear resonance fluorescence experiments, the scissors states in ^{163}Dy nucleus. The total B(M1)↑ strength S1 for (scissors) states around 3 MeV excitation is about 0.92 μ_N^2 and in addition the ratio R for the M1 decay strength for the state at 2.958 MeV to $7/2^-$ first excited state to the ground state $5/2^-$ state is observed to be 0.23. Moreover there is observed to be a total B(M1)↑ strength S2 ~ 0.85 μ_N^2 for states between 1.9 MeV and 2.5 MeV. This data for ^{163}Dy is analyzed using the analytical expressions derived by PRL scientists and all the observations are found to be in good accordance with the predictions of the SU(3) ⊗ U(2) symmetry model - the predicted values for S1, S2 and R are 0.86 μ_N^2, 0.91 μ_N^2 and 0.35 respectively. Thus we have the first experimental confirmation of the SU(3) ⊗ U(2) symmetry model for the scissor states in odd mass deformed nuclei. This work was done in collaboration with Y. D. Devi.

(V. K. B. Kota)

Order - Chaos Transitions in the Interacting Boson Model

Energy level fluctuations of quantal (many body) systems and random matrix models provide a path for defining the nature of quantum chaos. Interpolating random matrix ensembles corresponding to symmetry breaking gives rise to transition parameters and transition curves for order-chaos transitions and transitions from one type of chaos to another. The Interacting Boson Model (IBM) which accommodates dynamical symmetries provides an unified algebraic description of quadruple collective properties of atomic nuclei. The rich group structure of this model makes it amenable for fluctuation analysis and comparison with random matrix models by diagonalizing IBM hamiltonian matrices on one hand and classical trajectory analysis via coherent states on the other. Using the code SDGIBM1 developed in the past by PRL scientists, preliminary calculations for 20 boson system are carried out this year and identified a transition parameter that describes the order-chaos-order transitions in the interpolation of SU(3) and O(6) dynamical symmetry limits of IBM. This work is being carried out in collaboration with Y. D. Devi and R. U. Haq.

(V. K. B. Kota)

PARTICLE PHYSICS

Thermal Tunneling of $q\bar{q}$ Pairs in A-A Collisions

Consideration of various time scales in A-A collisions suggests that, it is relevant to determine $q\bar{q}$ pair production rate at finite temperature. We have evaluated this rate 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 $T^2 = 0$. This work was done in collaboration with P. K. Kaw.

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

A Collective Non-Abelian Mechanism for Colour Equilibration in Quark Gluon Plasma

A model is proposed for colour equilibration of quark gluon plasma. It is based on classical matrix kinetic equations for (quarks) gluons, and the equilibration arises from the non-abelian nature of colour dynamics. This work is done in collaboration with P. K. Kaw.

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

LEP Constraints on Extensions of the Standard Model

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 $SU(3)_C$ x $SU(2)_L$ x $U(1)_Y$ 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 Model comes from a larger group with a $SU(2)_L \times SU(2)_R$ symmetry. It was shown that the stringent bounds placed on $\sin^2\theta_w$ from a recent analysis of measurements at the Large Electron Positron collider rule out minimal SU(5) GUT and imposes a bound on the left-right symmetry breaking scale $M_R > 10^{10}$ Gev. We (with Biswajoy Brahmachari and K. Sridhar) have shown that the effect of gravity cannot be negligible near the GUT scale and if included through non-renormalizable higher order terms, it can make the minimal SU(5) GUT consistent with the LEP data as well as with large proton lifetime. We (this work was done in collaboration with Alakabha Datta and Sandip Pakvasa) also show that the constraints on the left-right symmetric GUTs models from LEP can be completely smeared out by effects of gravity and low energy left-right symmetry is also allowed. We (with Gautam Bhattacharyya, Amitava Datta and Amitava Raychaudhuri) have also studied the lower bound on the gauge boson masses of the left-right symmetric models by analyzing the LEP data. We give the most stringent model independent lower bound of 813 GeV on the right handed charged gauge bosons.

(Utpal Sarkar)

Baryogenesis via Leptogenesis

One of the most important problems in particle physics and cosmology is the question of baryogenesis. The large baryon asymmetry observed today corresponds to $\frac{n_B - n_{\bar{B}}}{n_B} \sim 3\times10^{-8}$ 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 criteria in grand unified theories (GUTs) at energies around 10^{15} GeV. However, it has recently 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. However, if there are C and CP violating out-of-equilibrium lepton number violation at energies around 10^{10} GeV, then through sphaleron effect it is possible to generate the required amount of baryon asymmetry during the electroweak phase transition. We have studied the question of CP violation in such scenarios (this work was done with A. Acker, H. Kikuchi and E. Ma). We (with Patrick J. O'Donnell) have also

identified new processes for generating baryon asymmetry in left-right symmetric theories through lepton number violation.

(Utpal Sarkar)

Three Lepton Decay Mode of the Proton

Muon neutrinos produced by cosmic rays in the atmosphere are expected to be almost twice as many as electron neutrinos. But the experimentally observed ratio of $R = N(\nu_\mu)/N(\nu_e)$ is almost half the expected ratio. The experiments look for "contained" events which are caused by neutrinos of energy below 2 GeV. Although the more popular explanation of this anomaly is neutrino oscillation, there is another explanation that if proton decays into a positron and two neutrinos $p \rightarrow e^+ + \nu\nu$ with a lifetime of 4×10^{31} years (this value is consistent with the present proton decay limit for this decay mode), then the excess "contained" electron events can actually be proton decay events. A mechanism for the three lepton decay mode for the proton was first proposed by us (this work was done in collaboration with Jogesh C. Pati and Abdus Salam), but then it was pointed out that it is difficult to incorporate this particular decay mode in those theories. We studied the three lepton decay modes of the proton within the proton decay interpretation of the atmospheric neutrino anomaly in a general way. We have constructed higher dimensional operators in the framework of the standard model and given the possible solutions. We presented a simple extension of the left-right symmetric model, which incorporates new light scalar particles, which can give rise to the desired proton decay mode. This work was done in collaboration with Patrick J. O'Donnell.

(Utpal Sarkar)

Two-Photon Process at High Energy $p\bar{p}$ Colliders

Production of new heavy charged particles in hadronic colliders could take place through the mechanism of fusion of two almost real photons, in addition to the more common mechanisms of quark-antiquark annihilation through a single virtual photon. Since the effective intensity of the almost real photons in a charged particle grows logarithmically with energy, the two-photon process has been suggested as a potentially useful mechanism. It was claimed in the past that the two-photon mechanism dominates over the $q\bar{q}$ annihilation mechanism for the production of a pair of heavy leptons or a pair of heavy scalar particles. This claim has been re-examined in the present work, and a careful calculation shows the claim to be untrue. This work was done in collaboration with M. Nowakowski, R. M. Godbole and M. Drees.

(S. D. Rindani)

Astrophysical Limit on the Gravitatino Mass

The theory of supergravity combines the feature of supersymmetry, that is fermion-boson symmetry, with the theory of gravity. A natural consequence of supergravity is the presence of a spin-3/2 partner of the graviton, called the gravitino, which derives its mass from the breaking of supersymmetry. In a class of theories, the gravitino ($\tilde{G}$) can be light, together with certain spin-zero parity even (S) and odd (P) particles which occur in these theories. In these theories, photon-matter and photon-photon interactions can produce S and P singly, or $\tilde{G}$, S and P in pairs, leading to an extra source for energy loss from astrophysical objects. Assuming this extra cooling to be small compared to the normal energy emission from the sun and red giants gives limits on the gravitino

mass which are several orders of magnitude better than the laboratory limits. This work was carried out with M. Nowakowski.

(S. D. Rindani)

CP Violating Interaction of τ Lepton

It is known for a long time that most weak processes respect a combination (CP) of charge conjugation (C) and parity (P) invariances, but not C and P separately. The only exception known so far is K-meson decay where CP is violated. This can be understood theoretically in the standard model (SM), which predicts that CP violation in most other sectors of the theory would be unobservably small. Any observation of CP violation in a leptonic system, for example, would be a definite indication that SM is not adequate. Presence of a CP-violating electric-dipole type of interaction of the tau lepton pair with Z has been looked for in e^+e^- collisions at LEP at CERN in Geneva by studying τ decay correlations. The present work suggests that in the presence of longitudinal e beam polarization, already available at the Stanford Linear Collider (SLC), a greater sensitivity to the CP-odd dipole coupling can be obtained. Polarization may be able to compensate for lower beam luminosity at SLC as compared to LEP.

(B. Ananthanarayan and S. D. Rindani)

Reconciling Solar and Atmospheric Neutrino Problem

The flux of the solar ν_e is experimentally found to be depleted compared to the theoretical expectations based on the standard solar model. Likewise, the flux of atmospheric neutrinos is also found to be depleted. It is pointed out that both these observations can be explained in terms of neutrino oscillations if all three neutrinos mix. Detailed comparison with experimental results was made and the region in the relevant parameter space allowed by the solar and atmospheric neutrino results was determined. This work was carried out in collaboration with P. Krastev.

(A. S. Joshipura)

Leptonic Flavour Violations and Extra Z

Extensions of the standard SU(2) x U(1) model are considered in which an extra gauge boson and an extra Higgs are introduced. All such models acting on leptons and allowed by renormalizability are classified. Detailed phenomenological analysis is made in one such typical model. It was shown that such models allowed for observable flavor violation in τ decay in spite of the strong constraints on Z-Z' mixing coming from the LEP results.

(G. Datta, K. B. Vijayakumar and A. S. Joshipura)

Degenerate Neutrino

It is pointed out that (i) the solar neutrino problem, (ii) atmospheric neutrino problem and (iii) need for hot component in the dark matter can be simultaneously understood if all three neutrinos are nearly degenerate in mass. It was shown that the near degeneracy of neutrino masses follow naturally in the seasaw model of neutrino masses.

(A. S. Joshipura)

Gluon Condensates, Quark Matter Equation of State and Quark Stars

Ground state structure of quantum chromo dynamics is known to be nontrivial with quark and gluon condensates. We have considered quark matter equation of state including strange quarks and a nontrivial structure for QCD vacuum with gluon condensates. Such a nonperturbative equation of state is applied to study structure of

compact stars using Tolman-Oppenheimer-Volkoff equations. Stable solutions for quark stars are obtained with Chandrasekhar limit as 3.2 $M_\odot$ and radii around 17 km. This work was done in collaboration with S.P. Misra and P. K. Panda.

(A. Mishra and H. Mishra)

Vacuum Structure in QCD with Quark and Gluon Condensates

We have considered here vacuum structure in QCD with both quark and gluon condensates and a variational ansatz for the ground state. The method is nonperturbative using only equal time algebra for the field operators. With a BCS type ansatz for QCD ground state we then find that a constrained energy minimisation of the Hamiltonian leads to a QCD vacuum with *both* quark and gluon condensates for strong coupling constant $\alpha_s > \alpha_c = 0.62\,\lambda$. Pion decay constant and the charge radius of pion seem to fix the QCD coupling constant α_s as 1.28. This approach appears to open up possibilities of relating the mysterious vacuum structure of QCD to common place hadronic properties. This work has been done in collaboration with S. P. Misra and P. K. Panda.

(A. Mishra, H. Mishra and Varun Sheel)

Confinement, Quark Matter Equation of State and Hybrid Stars

Lattice calculations in finite temperature QCD seem to indicate that the effect of confinement is still there beyond twice the critical temperature of quark hadron phase transition. Expecting a similar behaviour at high densities also, we have investigated the thermodynamic properties, in particular the equation of state for quark model taking confinement into account. We consider here the quark matter equation of state in a relativistic harmonic oscillator confining model at zero temperature. With a phenomenological parametrisation of neutron matter we see that a phase transition exists between the neutron matter phase and quark matter phase at about five to six times the nuclear matter densities. We have then studied the possibility of a hybrid star, namely a star consisting of both quark matter (core) and neutron matter (crust). Using Tolman-Oppenheimer-Volkoff equations with a given central density and appropriate equation of state we find that stable hybrid star with a quark core and a neutron matter crust can exist upto central density $\varepsilon_c \simeq 4.6$ GeV / fm^3 beyond which instability may result. For ε_c from 3 to 4.6 GeV / fm^3, the mass of the star varies between 1.8 $M_\odot$ to 1.98 $M_\odot$ and radii around 10 to 11 kms. The bulk of the hybrid star is provided by the neutron matter, the quark matter providing a core of about 1 to 2 km. We have also estimated other gross properties of such hybrid stars like moment of inertia, surface gravitational red shift and Keplerian rotation periods.

(S. B. Khadkikar, A. Mishra and H. Mishra)

Constraints on R-parity Violating Coupling in SUSY Models

The 1-loop evolution of couplings in the minimal supersymmetric standard model, extended to include baryon nonconserving operators through explicit R-parity violation, is considered keeping only baryon nonconserving superpotential terms involving the maximum possible number of third generation superfields. If all retained Yukawa couplings Y_i are required to remain in the perturbative domain ($Y_i < 1$) upto the scale of gauge group unification, upper bounds ensue on the magnitudes of the baryon nonconserving coupling strengths at the supersymmetry breaking scale, independent of the model of unification. They turn out to be similar to the corresponding fixed point values reached from a wide range of Y_i

(including all Y_i greater than unity) at the unification scale. The coupled evolution of the top and baryon nonconserving Yukawa couplings results in a reduction of the fixed point value of the former. This work was done in collaboration with Probir Roy.

(Biswajoy Brahmachari)

Low Energy Grand Unification with SU(16)

We study the possibility of achieving low unification scale in a grand unification scheme based on the gauge group SU(16). Baryon number symmetry being an explicit local gauge symmetry here gauge boson mediated proton decay is absent . We present in detail a number of symmetry breaking patterns and the Higgs field representations giving rise to the desired symmetry breakings and identify one chain giving low energy unification. These Higgs field representations are constructed in such a way that Higgs mediated proton decay is absent. We indicate the very rich low energy physics obtainable from this model which includes quark-lepton un-unified symmetry and chiral color symmetry. In brief some phenomenological implications are also studied.

(Biswajoy Brahmachari)

Nucleon Structure Functions

In view of data currently available for proton, neutron and deuteron targets, a global analysis of spin dependent structure function data has been done, with emphasis on the non-singlet sector. The sources of deviation of the data from *theoretical* expectations were pinpointed based, in particular, on the Bjorken Sum Rule. The conclusion is that apparent discrepancies can be reconciled so that the data are consistent with theory *provided the large-x limit is properly defined.* However, the current data have significant errors on them. If new data in the non-singlet (valence) sector become available which indicate that the large-x behaviour is *not* as predicted, this will have serious repercussions on our current understanding of deep inelastic scattering phenomena as well as question the validity of the till-now well established parton model. In our work, we have quantified the description of the non-singlet behaviour so that if such data is obtained, it will be a straightforward task to locate the region (large- or small-x) where deviations from canonical behaviour occur.

(D. Indumathi)

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COMPUTER CENTRE

The computer centre procured five IBM RS 6000/580 computer systems in October 1993 and are fully operational since January 1994.

Hardware

Each of these 5 systems uses IBM's POWER RISC architecture and has 38 MFLOPS Linpach (Double precision) rating. One of the system is having 64 MB RAM, two of them having 128 MB RAM, and the other two are with 512 MB RAM. The one with 64 MB RAM is having 12 GB disk space and the others are having 2.4 GB internal disk storage making a total of 21.6 GB disk space. All are having CD ROM and 1.44 MB floppy drives. Each is having 1280 x 1024,8 bit colour monitor with mouse. One of the systems with 512 MB RAM is equipped with image recorder for creating 35 mm film, slides etc from screen and the other with 512 MB RAM is having folsom colour graphics converter (CGC) to convert high resolution graphics to low resolution video.

Two of the systems with 128 MB RAM are having 32 RS 232 lines for connecting terminals and 2.3 GB 8mm DAT for back up. The system with 64 MB RAM and one of the systems with 128 MB RAM are having 1600/6250 bpi, 9 track magnetic tape drives. The system with 64 MB RAM is also having 2.3 GB, 8mm DAT for backup, two 800 1pm, dot band printers are attached to the systems.

The system having 12 GB disk storage is used as file server, The two systems having 32 serial lines with 128 MB RAM are used for time sharing and development jobs. The two systems with 512 MB RAM are used for large compute intensive production jobs. The system having CGC is used for applications needing creation of video tapes. The system having image recorder is used for applications needing creation of slides, film etc.

Six IBM X/150 X stations with 6 MB memory, 1280 x 1024, 8bit monitor and mouse are connected to the system, via ethernet network. Two colour screen printers for getting colour screen images are also procured. All the five IBM systems are connected by FDDI network.

Software

All the five systems have AIX OS (Compatible to standard UNIX). The IBM systems have FORTRAN, C++ and PASCAL compilers. The centre also procured the following software packages. MATHEMATICA, AVS, IMSL with EG, NAG, MACSYMA, QUINTUS, PROLOG, LISP.

Other Systems

The centre also acquired HP 9000/735 workstation with 40 MFLOPS rating. The system has 32 MB RAM and 1 GB disk space. The system has 1280 x 1024, 8bit colour monitor with mouse. It has 2.3 GB, 4mm DAT for backup. The system has hpux (compatible to standard UNIX) operating system. The system has FORTRAN, C compilers and IRAF.

The DEC-1091 is also operational for two shifts upto December 1993. As conversion to IBM 6000/580 is not complete the DEC-1091 is also operational subsequently for one shift and is catering to the needs of scientific community at large and other sections.

The centre is also equipped with two work stations DN 3500 and NEXUS 3000 and are connected with TOKEN ring network. Colour display monitors with keyboards and mouses are attached to them. One NEC P5-X2 printer is attached to them. The centre also possesses a PC/AT (BUSY BEE of HCL). HP735, APPOLO DN-3500, APPOLO DN-3000 are connected to IBM by ethernet network.

Research and Development

Research and development in computer related areas of numerical methods, statistics, oper-

ations research, neural network, modelling and simulation and library science is the main activity of centre besides consultation to users. The other activities include teaching to visiting members of PRL and space science students consultation, syllabus framing, staff selection and computer system selection for both internal and external.

Some of the research and development activities during the year are

- ★ Technique to identify the principal modes of variation in bivariate distribution functions.
- ★ Algorithm to study the amplitudes of the principal modes in bivariate distribution function using singular spectrum analysis.
- ★ Differencing techniques for solving deconvolution problems having an unknown indeterminate constant.

Training and Educational Activities

TISL has given a one week course on user application on IBM, another one week course on advanced system administration and a one week course on AIX/ 6000 LAN communication net work during January - March 1994.

HP-HCL has give a two-week course on user application and basic system administration during November-December, 1993.

ELECTRONICS LABORATORY

Electronics Laboratory is doing studies in the area of hardware and software for artificial Neural Networks. It is also engaged in developing sophisticated scientific instruments namely Fourier Transform Mass Spectrometer. Main thrust has been in the area of parallel processing neural network.

Artificial Neural Networks

Various types of Neural Network architecture were simulated and studied earlier. An integrated software package has been developed to be used in applications requiring more than one type of architecture. Neural networks are characterised by number of neurons and their connectivity. The choice of these parameters is more or less arbitrary. The computation cycles required for training the network depend on these two parameters and hence is crucial for training in large networks. The integrated package developed here has a optimization built into it, which reduces neurons and connectivity to a minimum required for the problem being trained. This feature was achieved by keeping time history of the neurons as they undergo training (weight adjustment). Also the type neuron (activation function) is selected optimally. The results of optimation algorithm showed different level of reduction in number of neurons and connectivity starting from an arbitrary number in the selected problems. The Exclusive - OR problem showed reduction by a factor of five in connection. Other examples such as identification of circle, hand written characters image band compression, prediction of time series showed varying degree of reduction in connectivity by a factor of 5 to 10.

Another important result obtained was with time delay neurons in a multilayered neural networks. These neurons improve the performance of the networks dealing with time varying signals such as ECG, EEG speech etc.

In the unsupervised learning the new algorithm proposed has been used to train multilayered network for the classification. The network was used to classify the character set of IBM PC into 32 classes using multilayer feed forward type network.

Parallel Processing Hardware

One of the most important aspect of neural computing is the inherent parallelism. It is possible to increase the speed or complexity almost linearly by increasing the number of processors, hence the product of cost and speed is important. A special arbitration logic is designed and implemented in FPGA to allow the two microcontrollers (CPU) to share the common RAM. One CPU dedicated to continuous adaptive training and other for I/O. This gives minimum communication, Overhead.

These modules are being connected in a tree type network to give high bandwidth and low output bandwidth.

Mass Spectrometer

A Prototype Fourier Transform ion cyctron Resonance Mass Spectrometer is being developed. The basic vacuum system has been set up which gives 10^{-9} Torr with help of sputter ion pump.

The mechanical fabrication of Trap cell is being done. The electromagnets have been set up to give about 1-5 kiloguass magnetic field. The DSP based digital filter data acquisition and processing electronics is in progress.

LIBRARY

Collection

The PRL Library subscribes 198 scientific and technical journals. A large number of scientific reports, data, maps, etc. are also received. 253 books were added to the Library.

Services

Over 1,26,000 photocopies were made according to requests received from PRL personnel, from other libraries and from research scholars outside PRL.

Requests were received for obtaining about 360 publications from other libraries on Inter-Library-Loan. Most of these publications were obtained on loan for our readers. About 216 publications were loaned by us to other libraries.

During the year, 8894 books and journals were issued. Several queries were received for providing factual information, locating addresses, giving biodata, preparing bibliographies etc.

Library Automation

It has been decided to use the central computing facility consisting of IBM Workstations for Library Automation. Since the library working will not depend on the campus wide Ethernet, as well as the FDDI Network of IBM workstations; 8 asynchronous lines connected to the IBM File server will be made available in the Library premises. Incidentally the high availability features available on IBM Workstations will be used for the Library Automation Programme.

A commercial software package has been purchased for Library Automation. The software has been ported on the IBM RS 6000/580 computer. The entire data comprising of the total library collection has been reformatted as per the new software. This involved considerable checking and rechecking.

Union Catalogue of Books

Since the machine readable book records in PRL Library did not contain the ISBN (International Standard Book Numbers), a project for assigning ISBN wherever available, was undertaken for the entire book collection, whilst conducting Stock Verification.

These numbers have also been added to the database. This has enabled us to start work on forming a Union Catalogue of Books available in IPR, PRL and SAC Libraries.

Network of Ahmedabad Libraries

A Proposal for Networking the Special Libraries of Ahmedabad (ADINET) was made. At the request of INFLIBNET, a feasibility study was undertaken of networking twenty five large libraries. This survey was undertaken to study : (1) the need for forming a network, (2) the existing resources and infrastructure and (3) to improve utilisation of resources. About 4500 periodicals are being subscribed for 1993 in 25 libraries. Out of these there are 3066 unique titles. The total book collection in 25 libraries is about eleven lakhs and the total 1992-93 budget is 356 lakhs - a vast resource which can be shared. A "Report on the Feasibility Study of Networking of Special Libraries of Ahmedabad - ADINET" was prepared, alongwith an "Union Catalogue of Journals subscribed by 25 libraries".

Resource Sharing

As per the decision taken during the DOS/ ISRO Librarians Resource Sharing Meeting a Union List of Commercial Databases and Databases produced inhouse in all the DOS libraries was compiled.

ENGINEERING SERVICES

The Engineering services render all technical services pertain to civil engineering works and related building and laboratory services such as electrical, public health, airconditioning, inter communication system, elevators, etc. right from the land acquisition to maintenance of all buildings (residential and non-residential and its related services for various campuses of the laboratory). The services also involved in planning, designing, estimating and execution of various works, horticultural development and maintenance and upkeepment of various buildings & campuses like PRL Campus, Staff Quarter Campus, Thaltej Campus, Gurushikar & Hill View Campuses, Udaipur Solar Observatory, etc. We also prepare sites for installation of sophisticated equipments meeting with clean room specifications.

During the year following works have been undertaken:

- ★ FRP lining works to 10 M MS Dome of Infrared Observatory Building, Mt. Abu.
- ★ Site Preparation works for:
  IBM RS 6000/580 Computer system.
  Stable Isotope Laboratory.
  Two Dimensional Infrared Array Detector and Associated Optics and Spectroscopy Laboratory

WORKSHOP

A new workshop has been set up at the Thaltej Campus. General facilities like machining, sheet metal, welding, assembly etc. have been provided and mechanics as well as supervisory staff are regularly available.

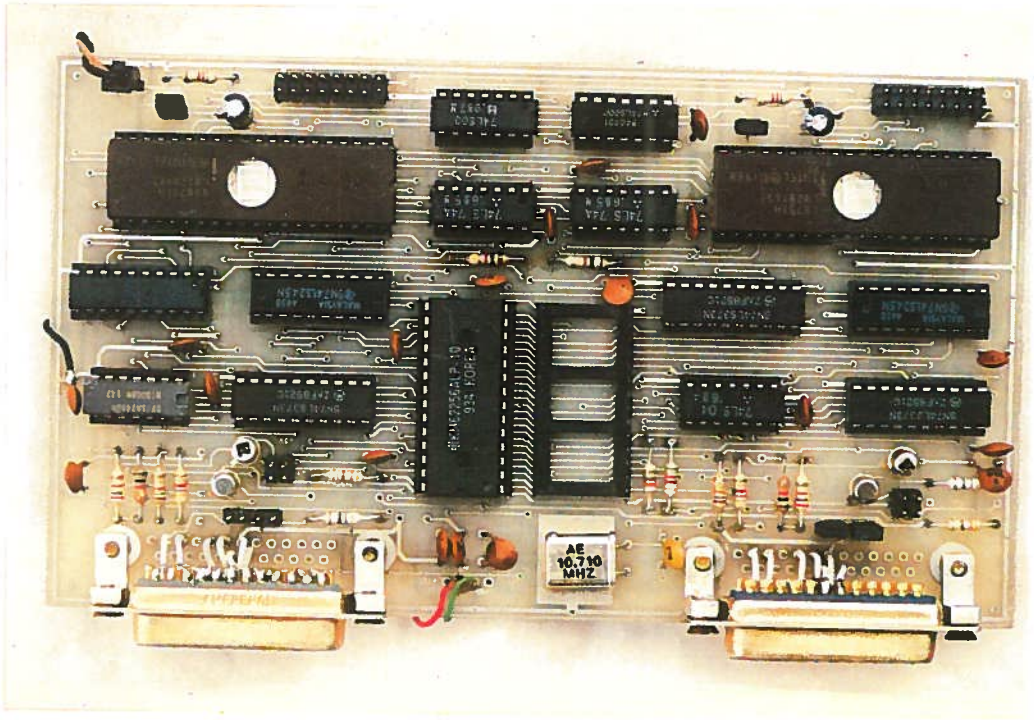
The important jobs undertaken at PRL workshop include a Day Time Photometer for use at Antarctica. It involved precision machining as well as machining operater and users cooperation between user scientist and workshop staff. The unit has been successfully used for data gathering during the Antarctica ezpedition. Apart from their fine focussing system, filter holders and aperture movement system were also fabricated.

A set of 1.5 meter corers of 100 mm diameter were developed for GEO-RS project to collect samples of sea water sediments. Multiple sample OSL system was also made for the same group.

Ultra high vacuum body assembly work as well as repairs of the same were carried out. Work on a plasma chamber is under process. Apart from this, precision machined nose tip LP sensor of stainless steel and ceramic insulate has been fabricated. A new airglow imaging system is being assembled and fine focussing mechanism has been completed.

Fabrication of peristatic pump head has been completed. Projector trollies and gear box assembly for the Robot arms have worked successfully. A dome of one meter diameter has been fabricated for observatory at Mount Abu. Apart from the above, general purpose miscellaneous fitting, assembly work and welding jobs have been carried out.

HARTMANN's screen with required accuracy was made for the INF-RD project, which would be utilized for testing the 48" diameter mirror of the IR telescope at Mount Abu. Pre amplifier boxes, antenna joint rewelding, telescope drive system maintenance and miscellaneous fitting and assembly jobs were carried out at Thaltej Campus. Precision machining and assembly work was done for the DEWAR and IR Polarimeter which reflects the level of excellence achieved by the mechanic concerned. The Dusty Plasma system and the system for the study of charged particle motion in the magnetic field were fabricated to the satisfaction of the user scientists.



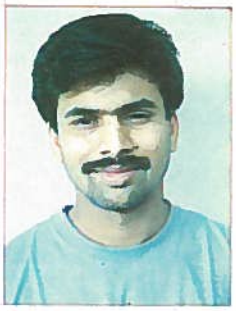
Shared memory dual microcontroller for adaptive training of artificial neural network.

"Hartmann's Screen" under preparation on radial drilling machine.
This screen will be utilised for testing the 48" diameter Mirror at Mt-Abu.

AWARDS AND HONOURS

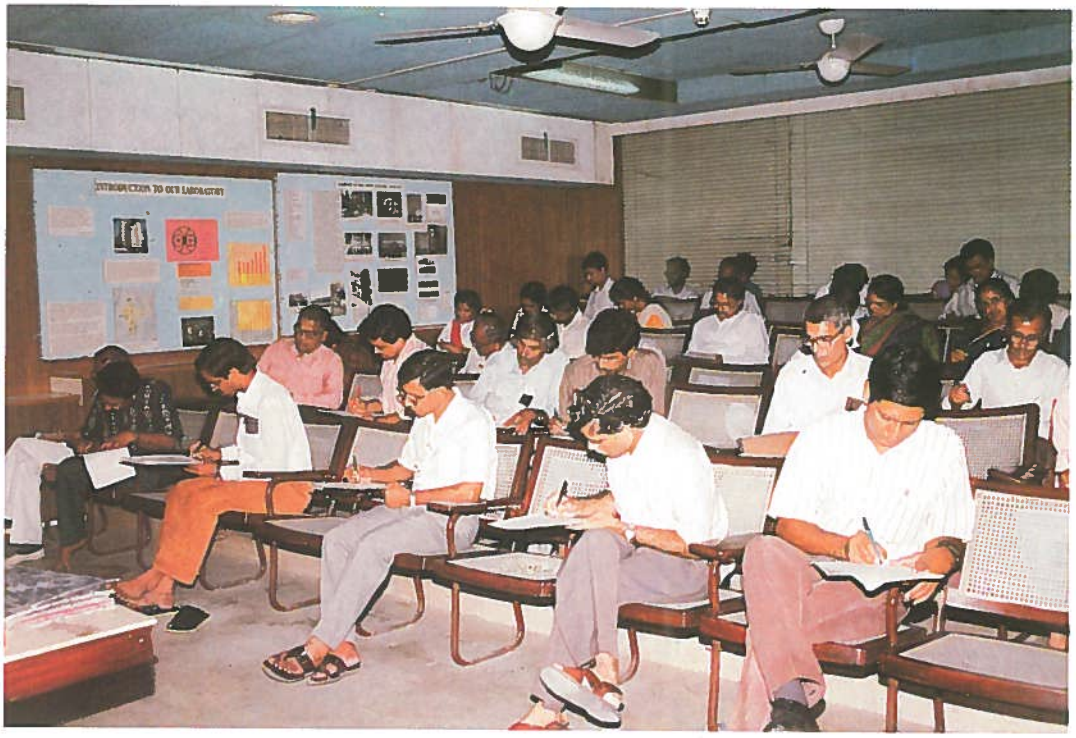
Dr. S. K. Bhattacharya

Elected Fellow of the National Academy of Sciences, Bangalore



Mr. J. S. Ray

Received cash prize for the best paper presented at the Sixth National Symposium on Mass Spectrometry, held in Dehra Dun, October 11-13, 1993.



Essay Writing Competition during the Hindi Week Celebration.

Prof. Amol Kumar Raychaudhuri, Seventeenth Vikram Ambalal Sarabhai Professor delivering a lecture.

School students participating in Science Quiz held during National Science Day at PRL

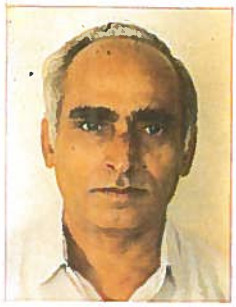
Prof. R. K. Varma, Director giving away the prizes to the winners of the Science Quiz held during National Science Day.

The Hindi Week was celebrated at PRL during 13-18 September, 1993. As a part of this celebration a number of programmes like word quiz, essay competition, popular lecture, Hindi films, elocution and recitation competitions were arranged. While most of the programmes were restricted to staff members only, the elocution and recitation competitions were open to the family members of the staff. The performances of our non-hindi speaking staff members and their family members were outstanding.

A mini workshop on High Energy Physics was held in PRL from November 2-6, 1993. During this meeting the developments in some of the fields which were to be covered later in the workshop on High Energy Particle Physics III, Madras, were reviewed and discussed. Emphasis was given to astroparticle physics and cosmology. There were talks and extensive discussions on Nucleosynthesis and Baryogenesis in the early universe, problems of atmospheric and solar neutrinos and dark matter and quantized red shift. Topics in particle physics which were covered were weak interaction phenomenology, collidem physics, phase transitions and strong interaction physics (with emphasis on quark-gluon plasma). There were pedagogical reviews of seventy five minutes duration and brief reviews of forty five minutes duration. In addition to the review talks, there were discussions and working group activities. About twenty five external and fourteen internal participants attended the mini workshop.

The laboratory celebrated the National Science Day on February 26, 1994 in collaboration with the Ahmedabad Chapters of Indian Physics Association and Indian National Science Academy. The programme, like earlier years, was dedicated to the students and science teachers of schools of Ahmedabad and Gandhinagar districts. Programmes like Science Manch for teachers and Science Quiz and popular science lectures for students were planned with the sole aim of creating scientific awareness amongst the school students. The programmes were open for students of classes IX to XI and were conducted in English and Gujarati.

Prof. Amol Kumar Raychaudhuri visited the laboratory as the seventeenth Vikram Ambalal Sarabhai Professor. Prof. Raychaudhuri is known internationally for his outstanding contribution in the fields of General Relativity and Cosmology, in particular for the discovery of the profound equation known by his name. During his two weeks stay at PRL Professor Raychaudhuri delivered four lectures on Bizarre Things in GTR. He also delivered an interesting popular lecture on Was there a Big Bang? in which he critically reviewed the observational and theoretical situations as is known today regarding our universe.

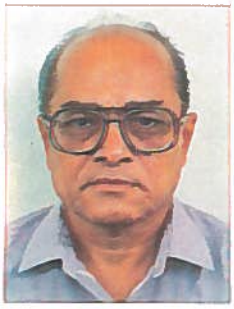


This year eight of our staff members retired from active service at PRL. Prof. B.H. Subbaraya, a distinguished and dedicated scientist completed thirty one years of service at PRL at the time of retirement. Prof. Subbaraya joined PRL as a research scholar in 1962. He was associated in the development of rocket borne Langmuir probe to measure electron density and other plasma parameters, in-situ over Thumba. In the early sixties with no infrastructure available this was a challenging task. Studies of the electron density irregularities were in fact one of the

outstanding contribution from PRL. Prof Subbaraya was awarded Ph.D. degree from Gujarat University in 1969. During early seventies Prof. Subbaraya was associated with the development of 'Aryabhatta', the first aeronomy satellite of India which has experiments on board to measure suprathermal electrons using retarding potential analyser and a Lyman ion chamber. In mid seventies he shifted his interest to topics related to middle atmosphere and was responsible for the development of the Lyman ion chamber for the measurement of oxygen profile and rocket borne photometers for the measurement of atmospheric ozone and aerosols. He was instrumental in evolving programmes using high altitude balloons for the measurement of trace gases, aerosols and ozone. His interest in green house gases led him to the development of sophisticated techniques at PRL like cryo-sampler, gas chromatography etc. One of his most recent contributions in the field of atmospheric sciences in PRL has been in initiating a major programme for probing the atmosphere by powerful lasers.

Shri P.P. Bhatt retired in July 1993 after two decades of dedicated service at PRL. Mr. Bhatt started his career with Western Railways in September 1951 and moved over to Gujarat State Road Transport Corporation in 1972. Mr.Bhatt joined PRL in September 1973 as Establishment Officer. His hard work and devotion brought him two promotions during his service of nearly two decades in PRL. Mr. Bhatt was known for his calm and cool headed temperament. This enabled him to have cordial relations with all staff members. He was looking after all legal matters. Mr. Bhatt was holding the post of Administrative Officer - II when he reached superannuation.

Shri Lalbhai C. Patel retired from PRL in August 1993 after a dedicated service of twenty seven years. After finishing his primary education Lalbhai joined PRL in 1966. While at PRL he passed the Electrical Supervisor Examination. At PRL Lalbhai was looking after all kind of electrical works. In addition, he was looking after the water supply system of staff quarters campus very efficiently.

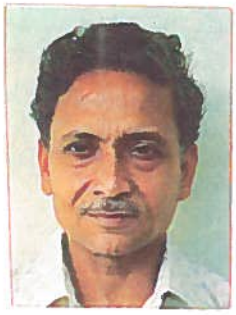


Shri B.A. Maniar retired from PRL in August 1993 after completing more than 25 years of service at PRL. He had his earlier education at Viramgam of Ahmedabad Distirct and graduated as an external student from Gujarat University. Shri Maniar started his career as a Land Surveyor in old Bombay State, then Sales Officer with Lipton Tea and worked with Western Railway prior to joining PRL. He joined PRL on June 4,1968 and worked in Purchase Section and had handled important import purchases such as Liquid Nitrogen Plant, DEC 10 Computer system and many other instruments and systems. Shri Maniar had wide ranging experiences while dealing with other Government agencies like DGTD, Customs, DOE etc. He possessed varied experiences in the area of materials management, import rules and regulation and strong communication skill. He is a

member of National Council of Materials Management and past Chairman of Ahmedabad Branch of Materials Management Association. More recently he has become President of Lions Club of Manavmandir and is actively associated with social activities.

Professor Bimla Buti retired in September 1993. Prof. Buti is one of the most eminent plasma physicists of our country. She did her Ph.D. work with Professor S. Chandrasekhar, a creator of many masterpieces in the world of science. Professor Buti made impressive achievements by contributing in all stages of the theoretical development of waves and instabilities in plasma; linear theories, effects of weak nonlinearities leading to solitons or solitaray waves and strong nonlinear interactions that can give rise to turbulence and chaos. Professor Buti's long scientific career has been very illuminating with many national and international awards, recognition and fellowship. She was awarded the Hari Om Ashram Prerit Vikram Sarabhai Research Award in 1977. She became a Fellow of Indian National Science Academy in 1980 and at present she is also a Council Member of the Academy for the period 1991-1994. She has been involved in the Plasma Physics activities of the International Centre for Theoretical Physics, Trieste, Italy and has been the Co-Director for the Plasma Physics Colleges arranged by the Centre since 1985. Prof. Buti became Fellow of the Third World Academy of Sciences in 1990 and obtained the Jawaharlal Nehru Birth Centenary Lecturership Award in 1993. After completing her term as Vice-President, Commission 49, International Astronomical Union (1988-91), she became President of the same Union for 1991-94. She was also the President, Plasma Science Society of India for 1992-93. In addition to her scientific achievements and world-wide recognition, the characteristics that command respect are her dedication, perseverance and hard work for the pursuit of scientific excellence.

Miss Pushpaben Dudhia was born on January 20,1934. She joined PRL as a Punch Operator on July 12, 1967 after taking her BA and BEd degrees from the Gujarat University. During her tenure of more than 26 years, she was promoted thrice and at the time of superannuation she was Scientific Assistant -B. She was also operating various computer machines. She operated IBM 1620, IBM 360/44, DEC 1091 and IBM 6000. Pushpaben retired from PRL on January 31, 1994.



Shri S.K. Banerjee retired from PRL as Engineer SD on 31 January 1994 after putting a very useful service of twenty five years in the Planetary Atmospheric Sciences Division. Shri S.K. Banerjee joined PRL on January 17th, 1969 after serving in the Indian Air Force for about 15 years. His first assignment was the development of a rocket-borne X-Ray astronomy payload under the guidance of Prof. U.R. Rao. Later he was associated with the development of rocket-borne UV photometers for the measurement of vertical distribution of ozone concentration. He participat-

ed in more than 20 rocket launchings from Thumba and had significantly contributed to the success of these sophisticated experiments. His cooperative nature and his systematic approach to the problems in hand were appreciated very much by his colleagues.

Shri A.J. Dosani was born on February 18, 1934. He joined PRL as Punch Operator on April 16, 1070 after passing S.S.C. from Bombay in 1954.

During his 24 years of service he was promoted three times and he was Technical Assistant B at the time of his retirement after superannuation. He also used to help in operating the computer systems, IBM 1620, IBM 360/44, DEC-1091 and IBM 6000. Shri Dosani retired from PRL on February 28, 1994.

Papers Presented at Symposia/Conference in 1993-94

ASTRONOMY ASTROPHYSICS

a. Seminar on M.N. Saha Centenary Celebrations, Calcutta, April 1993.

1. A.Bhatnagar, "Recent Developments in Solar Physics Research."

b. All-India Planetarium Directors' Conference, Calcutta, July 1993.

1. A.Bhatnagar, "Recent Trends in Planetarium Programmes."

c. XXIV Meeting of the American Astronomical Society/Solar PhysicsDivision, Stanford, USA, July 13-16, 1993.

1. A.Ambastha, M.J. Hagyard, and E.A. West, "Evolution and Flare-Associated Magnetic Shear Variation in Solar Active Regions."
2. M.J. Hagyard, E.A.West, J.E.Smith, A. Ambastha, and E.G. Kenny," A Study of Photospheric Magnetic Fields Associated with the June 1991 Active Region".

d. 6th Asia Pacific Regional Meeting on Astronomy of International Astronomical Union (IAU), IUCAA, Pune, August 16-18, 1993.

1. J. Anosova and B.G. Anandarao, "Dark matter around binary galaxies: Disruption of shells and formation of flows".
2. N.M. Ashok, T. Chandrasekhar, P.V. Watson and Sam Ragland, 'Near infrared observations of Serpentid binary systems V367 Cygni and UV Cancri".
3. A. Bhatnagar and S.C. Tripathy, "2- Dimensional Velocity Field Measurement of Eruptive Prominence Observed on 14 January 1993."
4. A. Bhatnagar, C. Debi Prasad, and Shibu K. Mathews, "Solar Observations using Lithium Niobate Fabry Perot Etalon."
5. A. Chakraborty, B.G. Anandarao, T. Chandrasekhar, J.N. Desai, R.Swaminathan and B. Lokanadham, "Rapid variability of H alpha emission line in Be stars".
6. C. Debi Prasad, "The Role of Critical Velocity Ionization in the Atmosphere of Io."
7. M.R. Deshpande and U.C. Joshi., "Detection of Microvariability in polarization in BL Lac object OJ287".
8. Rajmal Jain, and S.C. Tripathy, "H-alpha Intensity Oscillations Observed in Extended Flares."
9. U.C. Joshi, M.R. Deshpande, J.S. Chauhan, A.K. Senand A.K. Bhatnagar, "Imaging Polarimetry of Comet Austin".
10. Sam Ragland, T. Chandrasekhar and N.M. Ashok, "Angulardiameter of carbon star TX PISCIUM from Lunar Occultation observations in the near infrared".
11. P. Seema, B.G. Anandarao and D.P.K.Banerjee, "Velocity field structure in the Orion Display Nebula".
12. Nandita Srivastava, and Shibu K. Mathews, "3-Dimensional Velocity Structure of Quiet and Surge Prominences."
13. D.B. Vaidya and B.G. Anandarao., "Infrared emission from the HII regions: A detailed analysis of IRAS data".

e. IAU Symp. No.162 on "Pulsation, Rotation and Mass Loss in Early-Type Stars", Juan-les-Pins, Cote d'Azur, France, 4-8 October 1993.

1. B.G. Anandarao., A.Chakraborty, R. Swaminathan and B. Lokanadham., "Rapid variability of H alpha emission line in Be stars".

f. Professor Saha Centenary Celebration-International Conference on Astrophysics and Cosmology, Saha Institute of Nuclear Physics, Calcutta, 20-23 December 1993.

1. J. Anosova and B.G. Anandarao, "Dark matter in double galaxies".

g. XIV Mariond Astrophysics meeting on "Clusters of Galaxies", Les Arcs, Savoie, France, 12-19, March 1994.

1. J.Anosova and B.G.Anandarao, "Dark matter around binary galaxies".

h. Mini-Workshop on YOHKOH Results, Japan, March 29, 1994.

1. A. Bhatnagar, "Preliminary Results of 14 January 1993 Mass Ejectionin H-alpha and Soft X-rays."

PLANETERY ATMOSPHERE AND AERONOMY

a. National Symposium on the International Geosphere-Biosphere Programme, Madras, April 21-24, 1993.

1. Lal, M., Beig, G. and Chakrabarty D. K., "The Green House Effect of Water Vapour and its Variability".
2. B.H. Subbaraya, "The Ozone problem in global change studies" (Review talk).
3. Shyam Lal, B.H. Subbaraya and K.S. Modh, "Variability in the surface ozone at Ahmedabad".
4. S. Ramachandran, A. Jayaraman, Y.B. Acharya and B.H. Subbaraya, "Studies on Mt. Pinatubo volcanic aerosol layer using balloonborne photometer".

b. International FASAS Seminar on Global Environment Chemistry, New Delhi, September 27 to October 1, 1993.

1. Chakrabarty, D. K., "Ion-chemical schemes".

c. International Conference on regional environment and climate changes in East Asia, Nov. 30-Dec. 3, 1993, Taipei, Taiwan.

1. Shyam Lal, S. Venkatramani and B.H. Subbaraya, "Methane flux measurements from rice fields in Southern India".
2. B.H. Subbaraya, Shyam Lal, K.S. Modh and Manish Naja, "Monitoring of surface ozone at Ahmedabad".

d. Conference on Aerosol Science and Technology, BARC, Bombay, January 10-12, 1994.

1. A. Jayararnan, Y.B. Acharya and B.H. Subbaraya, "Study of Mt. Pinatubo volcanic aerosol layer over Ahmedabad using Nd:YAG laser lidar" (Invited talk).
2. S. Ramachandran, A. Jayaraman, Y.B. Acharya and B.H. Subbaraya, "Balloon studies of mode radius and number density of the Pinatubo volcanic aerosols during October 1991".

e. **National Symposium on Tropical Meteorology, I.I.T.M., Pune, February 11-14, 1994.**

1. A. Jayaraman, Y.B. Acharya, H. Chandra and B.H. Subbaraya, "Study of atmospheric structures using Nd:YAG lidar".
2. Y. Bhattacharya, A. Jayaraman, B.H. Subbaraya, B.M. Rao and P. Desai, "Determination of atmospheric dust content over ocean surfaces from INSAT VHRR data".
3. S. Ramachandran, A. Jayaraman, Y.B. Acharya and B.H. Subbaraya, "Investigation of the size distribution of the Pinatubo aerosols from balloonborne photometric studies."
4. S. Lal, Manish Naja, B.H. Subbaraya and Mr.Y.B. Acharya, "Ozone and its precursors at Ahmedabad".

f. **Workshop on Off median phenomena and International ionosphere, ICTP, Trieste, Italy, 19-22 October, 1993.**

1. Gupta, S. P., "Some features of equatorial E and F regions".

EARTH SCIENCES AND SOLAR SYSTEM STUDIES

Oceanography and Climate Studies

a. **7th Specialists Seminar on Thermoluminescence and Electron spin resonance dating held in Austria, February 5-9, 1993.**

1. Singhvi, A.K. and Banerjee, D. "Luminescence dating of dirty carbonate aggregates".
2. Singhvi, A.K., Banerjee, D., Pande, K., Gogte, V.D., Pant, R.K. and Valdiya, K.S., "Luminescence dating of neotectonic events in South Cenmtral Kumaon Himalaya".

b. **International Geosphere Biosphere Programme - National Symposium, Madras,April 21-24, 1993.**

1. Bhattachrya, S.K. and Jani, R.A., "Variation in concentration and isotopic composition of atmospheric carbon dioxidxe in India".
2. Chakraborty, S. and Ramesh, R., "Oxygen isotope studies on coral from Lakshadweep, India: Implications to sea surface temperature (SST) variations in the past".
3. Sarin, M.M. "Study of Indian river basins in the context of Global change".
4. Somayajulu, B.L.K., "Past environmental changes : High resolution studies using Arabian Sea sediments".
5. Sukumar, R., Ramesh, R., Pant, R.K. and Rajagopalan, G., "Palaeoclimate of South India - New results".

c. **PAGES Workshop on High Resolution records of past climate from monsoon Asia: The last 2,000 years and beyond, Taipei, Taiwan, April 21-23, 1993.**

1. Chakraborty, S. and Ramesh, R., "Isotopic investigation of environmental changes recorded in banded corals from the Arabian Sea"

d. **International Symposium and Workshop on Shifting desert margins and palaeomonsoons of the old world, Cairo, Egypt, September. 6-15, 1993.**

1. Singhvi, A.K., "Palaeoclimatic studies of the Thar Desert - an overview".
2. Singhvi, A.K., "Luminescence dating : Basic principles and present status".
3. Singhvi, A.K. and Banerjee, D., "Dating of pedogenic calcretes: A luminescence study".

e. **Palaeoclimate-93, University of Durham, Van Mildert College, UK September 22-25, 1993.**

1. Oldfield, F., Crooks, P., Peneberg, I., Thompson, T., Rose, N. and Nijampurkar, V.N., "The Geochronology of the last Millennium".

f. **6th National Symposium on Mass Spectrometry, Dehradun, October 11-13, 1993.**

1. Ramesh, R., Ray, J.S. and Pande, K., "Rayleigh isotopic composition from a multicomponent source".
2. Ray, J.S., Ramesh, R. and Pande, K., " Isotopic evolution of a phase that separates out of a reservoir that does not homogenise itself".

g. **American Geophysical Union Fall meeting, San Francisco, USA, December 6-10, 1993.**

1. Ramesh, R., "First evidence of Little Ice Age and Medieval Warming in India".

h. **International conference on Hydrology and Water Resources, New Delhi, December 20-22, 1993.**

1. Nema, P., Gupta, S.K., Sharma, P. and Ramaprasad, T.N.C., " Waste water renovation through soil aquifer treatment in the Sabarmati river bed at Ahmedabad".

i. **Prof. K.R. Ramanathan Centenary Symposium, PRL, Ahmedabad, December 18, 1993.**

1. Gupta, S.K. ,"Contribution of Prof. K.R. Ramanathan to local environmental problems.".

j. **Seminar on River Sabarmati, CEPT, Ahmedabad,. January 1-2, 1994.**

1. Gupta, S.K., Sharma, P., Nema, P. and Prasad, T.N.C., "Role of Sabarmati river in recycling and renovation of waste water at Ahmedabad".
2. Sharma, S.C., Gupta, S.K. and Sharma, P., "Artificial ground water recharge and waste water recycling: Potential and problems in the context of Ahmedabad and around".

k. **Field Workshop on Terminal Proterozoic and Lower Cambrian in India, Dehra Dun, January 3-8, 1994.**

1. Bhattacharya, S.K., "Carbon isotopic variations along a profile through Krol and Tal near Kauriyala, Garhwal, Syncline".

l. **81st Indian Science Congress, Jaipur January 4-6-1994.**

1. Krishnaswami S., Himalayan Orogency and marine geochemical cycles.

m. **Second workshop of Scientific Results of FORV Sagar Sampada, Cochin, February 15-17, 1994.**

1. Sarin, M.M., Rengarajan, R. and Somayajulu, B.L.K., " ^{234}Th-^{238}U, ^{210}Po-^{210}Pb and ^{210}Pb-^{226}Ra ratios in the Eastern Arabian Sea".

2. Somayajulu, B.L.K., Yadav, D.N., Rengarajan, R. and Sharma, "$CaCO_3$ and radiometric studies of sediment cores from the continental margins of the Eastern Arabian Sea".

Solar System and Geochronology

a. Sixth National Symposium on Mass Spectrometry, Dehra Dun, October 11-13,1993.

1. S.S. Rathore and T.R.Venkatesan, Ar- Ar age of synites from Mundwara alkali igneous complex, Rajasthan, India.
2. T.R.Venkatesan, Anil Kumar, K. Gopalan and D.C. Mukhamedov, Timing and duration of the Siberian volcanism.
3. Kanchan Pande, J.R. Trivedi and M.I. Bhat, Trace element and Sr isotope geochemistry of the Bhimital-Bhowali volcanics, Kumaun Lesser Himalayas.
4. J.R. Trivedi and Kanchan Pande, Rb/ Sr chronology of the Amritpur granites, Kumaun Lesser Himalaya.
5. Murty, S.V.S., Noble gases in a Muong Nong tektite.
6. Murty, S.V.S., Search for interstellar diamonds in Dhajala meteorite.
7. J.S. Ray, R. Ramesh and Kanchan Pande, Isotopic evolution of a phase that separates out of a reservoir that does not homogenise itself.
8. R. Ramesh, J.S. Ray and Kanchan Pande, Rayleigh isotopic fractionation from a multicomponent source.
9. Srinivasan, G., Ulyanov, A.A., and Goswami, J.N. "Time scales for the formation of early solar system objects".
10. Weidenbeck, M.W. and Goswami, J.N., "An ionprobe single zircon $^{207}Pb/^{206}Pb$ age from the Mewar gneiss at Thamorkotra, Rajasthan".

b. 25th Lunar and Planetary Science Conference, Houston, Texas, U.S.A., 14-18 March, 1994.

1. Mathew K.J. and Murty, S.V.S. (1994), Production rate of nitrogen in moon and meteorites.
2. Sahijpal, S., Goswami, J. N., Kashkarov, L.L., Korotkova, N.N. and Nazarov M.A. "Search for Mg isotopic anomaly in unequilibrated chondrites and unique meteorites".
3. Srinivasan, G., Goswami, J.N. and Ulyanov, A.A. "^{41}K excess in Efremovka CAIs".

c. Symposium on KT Events and other Catastrophies, Houston, 9-13 February 1994.

1. N. Bhandari, P.N. Shukla, Z.G.Ghevariya and S.M. Sundaram, KT Boundary in Deccan intertrappeans: Chemical anomalies and their implications.

d. LXXIX National Congress of the Italian Physical Society, 27 September-October, 1993.

1. C.Castagnoli, G.Bonino, C.Taricco and N.Bhandari, Variazione secolare dell'attivita solare nello spazio interplanetario evidenziata nell attivita del Ti in meteoriti cadute nell'ultimo secolo.

e. 56th Meteoritical Society Meeting, Vail, Colorado, U.S.A., July 19-23, 1993.

1. Murty, S.V.S., S. Sahijpal, A.V.Fisenko, L.P. Semjonova, Yu A. Shukolykov and J.N. Goswami, Microdiamonds from different meteorite types: N and noble gas studies.
2. Goswami J.N., S. Sahijpal, T.D. Swindle, D.S. Musselwhite and J.N. Grossman Ionmicroprobe studies of Iodine contents in silicate glasses and in Semarkona chondrules.
3. Sahijpal S., Ivanova M.A. and Goswami, J.N., Isotopic studies of Cr-Rich objects in the Raguli (H3.8) Chondrite.
4. Srinivasan G., Ulyanov A.A. and Goswami J.N. (1993), Search for ^{41}K excess in Efremovka CAIs.

THEORETICAL PHYSICS

Meteorology and Climate Studies

a. National Symposium on IGBP, Anna University, Madras, April 21- 24, 1993.

1. Satyan, V. and Kasture, S.V., "Modelling Studies related to IGBP".

b. Tropmet 93, National Symposium on Climate Variability, Indian Institute of Tropical Meteorology, Pune, February 8- 11, 1994.

1. Satyan, V., "Some Studies of Chaos using an Atmospheric Model".
2. Krishnan, R., Keshavamurty, R.N., Kasture, S.V. and Satyan, V., "Atmosphere-Ocean Coupling Effects on the Tropical Low Frequency Intraseasonal Variability".

Plasma Physics

a. Saha Centenary Symposium on Plasma Science and Technology, Allahabad, October 11-14, 1993.

1. Varma, R.K., " Observations of Discrete Allowed and Forbidden states in the charged particle Motion in a Magnetic Field" (inaugural address)
2. Das, A.C. and Sheikh, A.G., "A new Mechanism for Plasma Irregularities in Lower Ionospheric Plasmas"

b. Spring College on Plasma Physics, held at International Centre for Theoretical Physics, Trieste, Italy, 17 May 1993 - 11 June 1993.

1. Rao, N.N., "MHD Model for Magnetized Dusty Plasmas".

c. International Conference on Frontiers of Fundamental Physics, Olympia, Greece, September 27-30, 1993.

1. Varma, R.K., "Observations of Discrete Forbidden States in a Classical Mechanical System" (Invited Talk).

d. National Workshop on Recent Advances in Quantum Optics, Indore, March 7-10, 1994.

1. Varma, R.K., "Quantum-like Behaviour of Charged Particles in a Magnetic Field and Observation of Discrete Forbidden States in the Classical Mechanical Domain" (Invited Talk)

Atomic and Molecular Physics

a. **National Conference on Current Trends in Atomic and Molecular Physics, Bhabha Atomic Research Centre, Trombay, Bombay, December 21-23, 1993.**

1. Santhanam, M.S. and Sheorey, V.B., "Information Entropy and Localized Eigenstates of Chaotic Quantum Systems".
2. Dewangan, D.P., "Recent Developments in Charge Transfer in Energetic Ion-Atom Collisions" (Invited Talk).

b. **Eighteenth International Conference on Physics of Electronic and Atomic Collisions (XVIII ICPEAC), Aarhus, Denmark, July 21-27, 1993.**

1. Dewangan, D.P., "Electron Hydrogen Collisions in a Multiple Scattering Model".
2. Chakraborty, H.S., Sural, D.P. and Dewangan, D.P., "Rate Coefficients for Inelastic Transitions among the Excited States of Neutral Hydrogen, HeII and CVI".

Classical and Quantum Mechanics

a. **Workshop on Neuronal Modelling, Tata Institute of Fundamental Research, Bombay, September 27, 1993.**

1. Sarangi, S., "Modelling the EEG Time Series".

Nuclear Physics

a. **Charge Particle Spectroscopy and Reactions with Heavy Ions, Bangalore, June 16-18, 1993.**

1. Devi, Y.D. and Kota, V.K.B., "sdg Interacting Boson Model : Two Particle Transfer" (Invited Talk).

b. **Capture Gamma Ray Spectroscopy and Related Topics, held at Fribourg, Switzerland, September 20-24, 1993.**

1. Devi, Y.D. and Kota, V.K.B., "Two Quasi Particle Excitations in the SU(3) ⊗ U(2) Limit of IBF²M",

c. **International Workshop on Monte Carlo Methods in Nuclear Structure, held at Trento, Italy, March 14-25, 1994.**

1. Kota, V.K.B., "Principles and Applications of Statistical Nuclear Spectroscopy" (Invited Talk).

d. **Interchapter Meeting of Indian Physics Association Chapters of Gujarat State, held at M.S. University, Baroda, February 20, 1994.**

1. Kota, V.K.B., "Symmetry in Physics" (Invited Talk).

f. **TPSC Discussion Meeting on Chaotic Quantum Systems, Physical Research Laboratory, Ahmedabad, February 16-18, 1994.**

1. Kota, V.K.B., "Energy Level Fluctuations and Route to Quantum Chaos via Symmetries" (Invited Talk).

g. **Nuclear Physics Symposium, Calicut, December 27-30, 1993.**

1. Vinodkumar, P.C., Bannur, V.M. and Khadkikar, S.B., "Leptonic Decay Widths from Relativistic Harmonic Confinement Model".

Particle Physics

a. **Workshop on Coherent States : New Developments and Perspectives, School of Physics, University of Hyderabad, Hyderabad, October, 1993.**

1. Mishra, H., "Coherent States in QCD" (Invited Talk).

b. **Mini Workshop in High Energy Physics, Ahmedabad, November 2- 6, 1993.**

1. Sarkar, U., "Electroweak Baryogenesis - Phenomenology" (Review Talks - 2 lectures).
2. Parikh, J.C., "Production and Evolution of Quark Gluon Plasma" (Review Talks - 2 lectures).
3. Brahmachari, B., "Upper Bound on B Violating Yukawa Couplings from Renormalization Group Analysis" (Talk).

c. **International Conference on Non-Accelerator Particle Physics, Bangalore, January 2-9, 1994.**

1. Ganguly, A., Parikh, J.C. and Sarkar, U., "Baryogenesis through Lepton Number Violation at TeV Scale".
2. Brahmachari, B., O'Donnell, P.J. and Sarkar, U., "Proton Decay Solution of the Atmospheric Neutrino Problem".
3. Mishra, H., O'Donnell, P.J. and Sarkar, U., "Baryogenesis via Leptogenesis in Left-Right Symmetric Models".

d. **Workshop on High Energy Particle Physics, Institute of Mathematical Sciences, Madras, January 10-22, 1994.**

1. Rindani, S.D., "CP Violation at Colliders" (Invited Talk).
2. Joshipura, A.S., "Oscillating Neutrinos : Theory vs. Experiment" (Invited Talk).
3. Indumathi, D., "Spin Dependent Structure Functions" (Invited Talk).

e. **Workshop on Nuclear Equation of State, Puri, January 1994.**

1. Mishra, A., "Gluon Condenstates, Quark Matter Equation of State" (Seminar)

COMPUTER CENTRE

Fourth International Conference on Precipitation, University of IOWA, IOWA city, April 26-28, 1993.

1. R. Suhasini, "Hydrological and meterological aspects of raingall measurement and predictability"

Thesis Submitted During 1993-94

1. **Krishnan R.**

   Dynamics of Large Scale Heat Induced Circulations in the Tropical Atmosphere (April 1993)

2. **Srivastava N.**

   Dynamic Phenomena on the Sun (August 1993)

3. **Chakraborty S.**

   Environmental Significance of Isotopic and Trace Elemental Variations in Banded Corals (December 1993)

4. **Avijit Ganguly**

   Production and Pre-equilibrium Evolution of Quark Gluon Plasma (December 1993)

5. **Lal M.**

   Some Studies of Minor Neutral Constituents of the Middle Atmosphere of Low Latitude (January 1994)

6. **Samal M.C.**

   Some Studies in Standard Model and Beyond (January 1994)

7. **Brahmachari B.**

   Constraints on Unified Theories in the Light of LEP Results (February 1994)

Symposium / Workshop Organised at PRL

1. Mini Workshop on High Energy Physics; November 2-6, 1993

Conferences/Symposia Attended during 1993-94

ASTRONOMY & ASTROPHYSICS

Dr. M.R. Deshpande

Dr. H.O.Vats

Rajkot

Third coordinated data analysis workshop of satellite scintillation network under AICPITS, Saurashtra University, 12-17 April 1993

Dr. Ashok Ambastha

Tucson, USA

Annual GONG Meeting, April 19-21, 1993

Dr. A. Bhatnagar

Calcutta

Seminar on M.N. Saha Centenary Celebration, April 1993.

All-India Planetarium Director's Conference, July 1993.

Dr. Ashok Ambastha

Stanford, USA

XXIV Meeting of the American Astronomical Society/Solar Physics Division, July 13-16, 1993.

Dr. J. Anosova

Dr. B.G. Anandarao

Dr. N.M. Ashok

Dr. D.P.K. Banerjee

Dr. A. Bhatnagar

Mr. A.D. Bobra

Mr. A. Chakraborty

Dr. T. Chandrasekhar

Dr. C. Debi Prasad

Dr. M.R. Deshpande

Dr. Rajmal Jain

Dr. P. Janardhan

Dr. U.C. Joshi

Mr. Shibu Mathews

Mr. Sam Ragland

Mr. P.V. Watson

Dr. H.O.Vats

IUCAA, Pune

6th Asia Pacific Regional Meeting on Astronomy, August 16-20, 1993.

Dr. N.M. Ashok

IUCAA, Pune

Miniworkshop on Cataclysmic Variables, August 23 - 25, 1993.

Dr. U.C. Joshi

IUCAA, Pune

International workshop on AGNs and QSOs, October 5-20, 1993.

Dr. B. G. Anandarao

Cote-d'Azur, France

IAU Symposium No.162 on "Pulsation, Rotation and Mass Loss in Early-Type Stars", October 4-8, 1993.

Dr. J. Anosova

Saha Institute of Nuclear Physics, Calcutta

Prof.Saha's Centenary - "International Conference on Astrophysics and Cosmology", December 20-23, 1993.

Dr. J. Anosova

Les Arcs, Savolie, France

XIV Mariond Astrophysics Meeting on "Clusters of Galaxies", 12-19 March, 1994.

Dr. A. Bhatnagar Tokyo, Japan

Mini-Workshop on Yohkoh results, 29 March 1994.

PLANETARY ATMOSPHERES AND AERONOMY

Mr. Y. B. Acharya

Dr. A. Jayaraman

Mr. S. Ramachandran

Bombay

Conference on Aerosol Science and Technology, BARC, Bombay, January 10-12, 1994.

Dr. S. P. Gupta

Dr. Shyam Lal

Dr. B.H. Subbaraya

Mr. Manish Naja.

Madras

National Symposium on International Geopshere-Biosphere Programme, April 21-24, 1993, Madras.

Dr. Shyam Lal

Dehra Dun

Sixth National Symposium on Mass spectrometry, October 11-13, 1993, Dehra Dun

Taiwan

International conference on regional environment and climate changes in East Asia, November 30 - December 3, 1993, Taipei, Taiwan.

Dr. H. Chandra

Rajkot

Third SS network data analysis workshop, Saurashtra University, Rajkot, 12-17 April 1993.

Waltair

Second SERC School on "Upper Atmosphere", Andhra University, Waltair, August 1993.

Dr. B.H. Subaraya

Dr. Shyam Lal

Dr. Manish Naja

TROPMET-1994 Symposium February 8-11, 1994, Pune,

Dr. S. P. Gupta

Italy

Workshop on Off Median phenomena and international ionosphere, 19-22 October, 1993.

EARTH SCIENCES AND SOLAR SYSTEM STUDIES

Oceanography and Climate Studies

Mr. S. Charkaborty

Taipei, Taiwan

Pages Workshop on High Resolution Records of Past Climate from Monsoon Asia : The last 2000 years and Beyond, April 21-23, 1993.

Dr. V.N. Nijampurkar

Vienna, Austria

IAEA Advisory Group meeting on "Soil Erosion", Vienna, Austria, April 26-29, 1993.

Dr. R. Ramesh

Dr. M.M. Sarin

Dr. B.L.K. Somayajulu

Madras

IGBP National Symposium , Madras, April 21-24, 1993.

Dr. R. Ramesh

San Francisco. USA

American Geophysical Union Fall meeting, December 6-10, 1993.

Dr. R. Ramesh

Mr.J.S. Ray

Sixth National Symposium on Mass Sepctrometry, October 11-13, 1993.

Dr. A. K. Singhvi

Krems, Austria

7th Specialist Seminar on TL/ESR dating, July 3-8, 1993.

Cairo, Egypt

IGCP-349 Workshop on Shifting Desert Margins and Palaeomonsoons of the old world, September 5-15, 1993.

London, UK

International Symposium on Wind blown sediments in the quaternary record, January 5-8, 1994.

Dr. M.M. Sarin

Dr. B.L.K. Somayajulu

Cochin

Second Workshop on Scientific Results of FORV Sagar Sampada, February 15-17, 1994.

S. Krishnaswami

Jaipur

81st Indian Science Congress, January 4-6, 1994.

Solar System and Geochronology

Dr. T.R.Venkatesan

Dr. K. Pande

Dr. M. Weidenbeck

Dr. J.R.Trivedi

Dr. S.V.S. Murty

Dr. G. Srinivasan

The Sixth National Symposium on Mass Spectrometry, October 11-13, 1993.

Dr. N. Bhandari

Houston, U.S.A.

K/T Event and other catastrophes in Earth's History, 9-13 February, 1994.

Dr. J.N. Goswami

Mr. S. Sahijpal

Kavalur, India

SERC School on Astronomy and Astrophysics, organised by Indian Institute of Astrophysics, Bangalore, 1-6 February, 1994.

Dr. J.N. Goswami

Vail, Colorado, USA

56th Annual meeting of the Meteoritical Society, July 19-23, 1993.

La Jolla, California, USA

Symposium in honour of Prof. J.R. Arnolds 70th Birthday, July 28, 1993.

THEORETICAL PHYSICS

Meteorology and Climate Studies

Mr. S.V. Kasture

Madras

National Symposium on International Geosphere Biosphere Programme, Anna University, April 21-24, 1993.

Mr. B. Thomas

Pune

Tropmet-94, National Symposium on Climate Variability, Indian Institute of Tropical Meteorology, February 8-11, 1994.

Plasma Physics

Dr. A.C. Das

Allahabad

Saha Centenary Symposium on Plasma Science and Technology, October 11-13, 1993.

Dr. N.N. Rao

Trieste, Italy

Spring College on Plasma Physics, International Centre for Theoretical Physics, 17 May - 11 June, 1993.

Visakhapatnam

Second SERC School on Upper Atmospheric Physics, Andhra University, 16 August - 3 September, 1993.

Dr. R.K. Varma

Greece

International Conference on the Frontiers of Fundamental Physics, Olympia, September 27-30, 1993.

Allahabad

Saha Centenary Symposium on Plasma Science and Technol-

ogy, October 11-13, 1993. Delivered the Inaugural Address.

Calcutta

International Conference on Bose and 20th Century Physics, December 30, 1993 - January 3, 1994. Presented a paper.

Indore

National Workshop on Recent Advances in Quantum Optics, March 7-10, 1994. Gave a talk on "Quantum-like Behaviour of Charged Particles in a Magnetic Field and Observation of Discrete Forbidden States in the Classical Mechanical Domain.

Atomic and Molecular Physics

Dr. V.B. Sheorey

Mr. M.S. Santhanam

Bombay

National Conference on Current Trends in Atomic and Molecular Physics, Bhabha Atomic Research Centre, Trombay, December 21-23, 1993.

Dr. D.P. Dewangan

Denmark

Eighteenth International Conference on Physics of Electronic and Atomic Collisions (XVIII ICPEAC), Aarhus, July 21-27, 1993.

Bombay

National Conference on Current Trends on Atomic and Molecular Physics (CURTAMP '93), Bhabha Atomic Research Centre, December 21-23, 1993.

Classical and Quantum Mechanics

Dr. S. Sarangi

Bombay

Workshop on Neuronal Modelling, Tata Institute of Fundamental Research, September 27, 1993.

Nuclear Physics

Dr. V.K.B. Kota

Dr. Y.D. Devi

Friburg, Switzerland

International Symposium on Capture Gamma Ray Spectroscopy and Related Topics, September 20-24, 1993.

Dr. V.K.B. Kota

Trento, Italy

International Workshop on Monte Carlo Methods in Nuclear Structure, March 14-25, 1994.

Ahmedabad

TPSC Discussion Meeting on Chaotic Quantum Systems, February 16-18, 1994.

Baroda

Interchapter Meeting of Indian Physics Association Chapters of Gujarat State, M.S. University, February 20, 1994.

Dr. Y.D. Devi

Bangalore

Charge Particle Spectroscopy and Reactions with Heavy Ions, June 16-18, 1993.

Dr. S.B. Khadkikar

Bangalore

International Conference on Non-Accelerator Particle Physics, Indian Institute of Astrophysics, January 2-9, 1994.

Trieste, Italy

Sixth Workshop on Perspectives in Nuclear Physics at Intermediate Energies, International Centre for Theoretical Physics, May 3-7, 1993.

Particle Physics

Dr. J.C. Parikh

Dr. U. Sarkar

Dr. S.D. Rindani

Dr. A.S. Joshipura

Dr. H. Mishra

Dr. A. Mishra

Dr. D. Indumathi

Mr. A. Ganguly

Mr. Varun Sheel

Mr. P. Poulose

Ahmedabad

Mini Workshop in High Energy Physics, November 2-6, 1993.

Mr. Varun Sheel

Mr. P. Poulose

Guwahati

IX SERC School in Theoretical High Energy Physics, Gauhati University, November 1-27, 1993.

Dr. J.C. Parikh

Dr. A.S. Joshipura

Dr. S.D. Rindani

Dr. H. Mishra

Dr. D. Indumathi

Mr. A. Ganguly

Mr. B. Brahmachari

Madras

Workshop in High Energy Physics Phenomenology, January 10-22, 1994.

Dr. S.D. Rindani

Dr. H. Mishra

Dr. D. Indumathi

Bangalore

International Conference on Non-Accelerator Particle Physics, January 2-9, 1994.

Dr. S.D. Rindani

Italy

Summer School on High Energy Physics and Cosmology, Trieste, June 14 - July 9, 1993.

Mr. B. Brahmachari

Ahmedabad

Mini Workshop on Particle Physics Phenomenology, November 1993. Gave a talk on "Upper Bound on B Violating Yukawa Couplings from Renormalization Group Analysis".

Bangalore

International Conference on Non-Accelerator Particle Physics (LO-ICNAPP), Indian Institute of Astrophysics, January, 1994. Gave a talk on "Proton Decay Solution of the Atmospheric Neutrino Problem".

Dr. A. Mishra

Puri

Workshop on Nuclear Equation of State, January, 1994. Gave a seminar on "Gluon Condensates, Quark Matter Equation of State".

Dr. H. Mishra

Hyderabad

Workshop on Coherent States: New Developments and Perspectives, School of Physics, University of Hyderabad, October, 1993. Gave a seminar on "Coherent States in QCD" (Invited Talk).

LIBRARY

Rhoda Bharucha

Ahmedabad

Seminar on Further Thinking on Resource Sharing at ATIRA during October 5, 1993. Gave a talk on THE "Feasibility Study of Networking of Special Libraries of Ahmedabad (ADINET)

Rhoda Bharucha

Ahmedabad

Workshop on Management Information Product Design & Test Marketing at IIM November 27-28, 1993

Rhoda Bharucha

Ahmedabad

National Convention on Automation of Libraries in Higher Education & Research Institutes held by INFLIBNET February 19-20, 1994

Rhoda Bharucha

Ahmedabad

The Impact of Information Technology on Library Services, at Gujarat Vidhyapith March 23-25, 1994.

COMPUTER CENTRE

Mr. G.N. Desai

Bombay

28th CSI Annual convention, November 1993.

Mr. M.S. Patel

Ahmedabad

Seminar on computer Network in India, November 1993

Visits to Universities/Research Organizations and Talks given there during 1993-94

ASTRONOMY AND ASTROPHYSICS

Dr. H.O.Vats

Rajkot

Saurashtra University, and gave two talks on "Scintillation Theory I & II, and a popular lecture on "The Universe", in April 1993.

Dr. A. Ambastha

Huntsville, USA

Visited Solar Science Branch, NASA Marshall Space Flight Centeras Senior NASA/NRC Associate,and gave a talk "Evolutionary and Flare-Associated Magnetic Shear Variations in Solar Active Regions" on July 6, 1993.

Dr. N.M. Ashok

IUCAA, Pune

Gave an Invited talk on Infrared observational studies of Classical Novae, August 1993.

Dr. U.C. Joshi

IUCAA, Pune

Gave a seminar on Micro variability of BL Lacobjects, October 1993.

Dr. B.G. Anandarao

Meudon, France

Visited the IR Astronomy Group, Observatoire de Meudon, France, and gave a seminar on Mass loss process in Mira Variables in October 1993.

Dr. H.O. Vats

Rajkot

Saurashtra University, and gave the following 5 lectures on:

1. Introduction to Astronomy
2. Demonstration of IPS telescope
3. Life of a star
4. Radio Telescope &
5. Interplanetary Scintillation, during October 20-22, 1993.

Dr. P. Janardhan

Ooty, India

Was deputed to the Radio Astronomy Centre, Ooty between 1 February 1994 and 30 April 1994. Gave a talk on Interplanetary Weather, October 1993.

Dr. A. Bhatnagar

Mitaka, Japan

Visited National Astronomical Observatory, Solar Division, in March 1994 and gave a colloquiumon (i) "Preliminary Results of Collaborative Study of H- alpha and Soft X-ray YOHKOH Observations of14 January1993 Mass Ejection Event", and (ii) "Lithium Niobate FP Solar Video Magnetograph and Flare of 27 February 1992".

PLANETARY ATMOSPHERES AND AERONOMY

Dr. H. Chandra

Rajkot

Visited Saurashtra University and gave talk on "Spaced receiver technique" during April, 1993.

Dr.H. Chandra

Waltair

Visited Andhra University and gave three lectures on "Ionospheric Irregularities" during August, 1993.

Dr. H. Chandra

Nagpur

Visited Nagpur University and gave a talk on "Aeronomy Research at PRL" during August, 1993.

EARTH SCIENCES AND SOLAR SYSTEM STUDIES

Oceanography and Climate Studies

Bhattacharya, S.K.

Calcutta

Visited the School of Oceanographic Studies, Geology Department of Jadavpur University and delivered two lectures on Palaeooceanography and Isotope Geochemistry on December 27, 1993.

Dr. Gupta, S.K.

Dr. Sharma, P

Gandhinagar

Attended the British Council sponsored training course on Groundwater Development in Gujarat Jalseva Training Institute, on January 12, 1994 and gave talks.

Dr. Pant, R.K.

Lucknow

Visited the UP Remote Sensing Application Centre and gave two lectures on Reconstruction of past climates from geological records : Loess deposits and glacial moraines, March 18, 1993.

Dr. Ramesh, R.

Gandhinagar

Visited the Geological Survey of India in September 1993 and gave a talk on Climatic changes in earth's history.

Kalamazoo, USA

Visited the Institute of Water Resources , Western Michigan University and gave a talk on Short and long term climatic variations in India during January, 1994.

Dr. Singhvi, A.K.

Heidelberg, Germany

Gave a talk on A review of luminescence studies at PRL at the Max-Planck Institute for Kern Physik, during January, 1994.

Frieberg, Germany

Visited the Department of Applied Physics of University of Frieberg and gave a talk during January 1994.

Kiel, Germany

Visited the Geography Department of the University of Kiel and gave a talk.

Dr. Somayajulu, B.L.K.

Bombay

Visited the Tata Institute of Fundamental Research and gave a colloquium on Cosmic Rays, Beryllium-10 and Oceanography on November 17, 1993.

Dr. T.R.Venkatesan

Dehra Dun, India

Visited K.D.Malavya Institute of Petroleum Exploration and gave a seminar on "The Deccan volcanism in India, 65 Ma ago".

Lucknow, India

Visited Birbal Sahni Institute of Paleobotany and gave a seminar "On the time and duration of the Deccan volcanism."

Dr. Kanchan Pande

Roorkee, India

Visited Department of Earth Sciences, Roorkee and gave a seminar on "^{40}Ar-^{39}Ar chronology of Deccan volcanism" on 15th October, 1993.

Dr. N. Bhandari

Gandhinagar

Geological Survey of India, Gandhinagar. Gave a seminar on "Cretaceous Tertiary Boundary problem in Earth's History".

Dr. J.N. Goswami

Kavalur

Gave lectures in a school on "Advanced stages of stellar evolution" held in February 1994 at the Vainu Bappu Observatory, Kavalur on

a) Solar Stellar Relationship.

b) Interstellar Dust in Meteorites.

Bangalore

Gave three lectures in an Astronomy Summer School held at Indian Institute of Science, Bangalore on "Origin and evolution of the solar system", June 1993.

Los Angeles, USA

Visited University of California, Los Angeles and gave a talk in the Dept. of Earth and Space Sciences, August 1993.

THEORETICAL PHYSICS

Astrophysics

Dr. A.R. Prasanna

Baroda

M.S. University, on December 20, 1993. Gave a Seminar on 'Nobel Prize in Physics - 1993' (under the auspices of Physics Department and Indian Physics Association).

Bombay

Physics Department, Indian Institute of Technology, during February 27 - March 1, 1994. Gave a Seminar on 'Nobel Prize in Physics - 1993'.

Bangalore

Indian Institute of Astrophysics, during March 2-9, 1994. Gave a Colloquium on 'Centrifugal Force Reversal in General Relativity'.

Meteorology and Climate Studies

Dr. V. Satyan

Ahmedabad

Department of Physics, Gujarat University, in February 1994. Gave a Course on 'Dynamic Meteorology'.

Plasma Physics

Dr. N.N. Rao

Visakhapatnam

Department of Physics, Andhra University, August 16 - September 3, 1993. Gave a series of four lectures on 'Eloementary Kinetic Theory' for the participants in the SERC School.

Dr. R. K. Varma

Hyderabad

Department of Physics, Universityof Hyderabad, November 26- 27, 1993. Gave a talk on "Observations of Discrete Allowed and Forbidden States in the Charged Particle Motion in a Magnetic Field.

Classical and Quantum Mechanics

Dr. S. Sarangi

Bhubaneswar

Institute of Physics, April 2, 1993. Gave a talk on "Modelling the Neural Networks - An Introduction".

Dr. V.B. Sheorey

Delhi

School of Physics Sciences, Jawaharlal Nehru University, June 24, 1993. Gave a seminar on "Quantum Eigen-functions of a Chaotic System".

Pune

Department of Physics, University of Poona, January 27-29, 1994. Gave a Seminar on 'Eigenfunction Structures in Chaotic Quantum Systems'.

Bhubaneswar

Institute of Physics, during January 30 - February 6, 1994. Gave two talks on (a) Calculation of Highly Excited Eigenstates, and (b) Structures in Eigenfunctions of Chaotic Quantum Systems.

Nuclear Physics

Dr. S.B. Khadkikar

Italy

International Centre for Theoretical Physics, Trieste, in May-June, 1993.

Germany

Institut fur Theoretische Physik, Universitat Tubingen, Tubingen, in April 1993.

Dr. V.K.B. Kota

Calcutta

Inter-University Consortium for DAE Facilities, Calcutta Centre, during July 5-23, 1993. Gave a series of lectures on 'Nuclear Shell Model and the Interacting Boson Model'.

France

Centre de Recherches Nucleaires, Universite Louis Pasteur, Strassburg, during September 15-18, 1993. Gave a talk on 'Nuclear Level Densities and Spectral Averaging Theory'.

USA

Department of Physics, University of Rochester, during September 27 - October 21, 1993. Gave a talk on 'Group Representation Matrix Elements in Eikonal Scattering and Sub-barrier Fusion'.

The Netherlands

Kernfysisch Versneller Instiutut, Groningen, during November 1-5, 1993. Gave a talk on 'Nuclear Level Densities and Spectral Averaging Theory'.

New Delhi

Jawaharlal Nehru University, during November 10-12, 1993. Gave a talk on 'Dynamical Symmetries in Nuclear Physics'.

Particle Physics

Mr. A.K. Ganguly

Baroda

Physics Department,M.S University of Baroda in September 1993. Gave a seminar on 'Production and Preequilibrium evolution of Quark Gluon Plasma'.

Dr. U. Sarkar

USA

Physics Department, University of California at Riverside, California. Gave a seminar on 'Phenomenological Constraints on Left-Right Symmetric Models'.

Canada

Physics Department, University of Toronto, Toronto. Gave a seminar on 'Baryogenesis through Lepton Number Violation'.

Physics Department, University of Waterloo, Waterloo. Gave a seminar on 'Leptogenesis in Left-Right Symmetric Models'.

Dr. S.D. Rindani

Germany

Karlsruhe University, Karlsruhe, June 6-13, 1993. Gave a talk on "Experimental Limits on Higgs Mass in Majoron Models".

Mr. B. Brahmachari

Bombay

Tata Institute of Fundamental Research, April-May and July, 1993. Gave a talk on "Low Energy Grand Unification".

COMPUTER CENTRE

C.S.R. Murty

Ahmedabad

Department of Physics, Gujarat University, gave a course on Data processing in February-Mar 1994.

ELECTRONIC LABORATORY

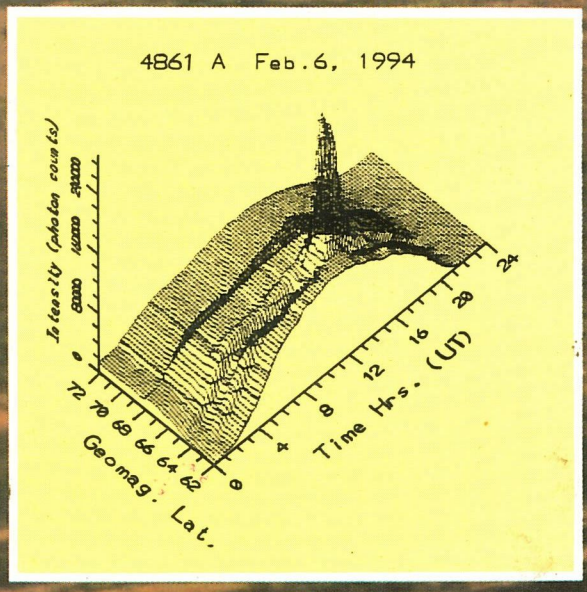
Mr. H.S. Mazumdar

Bangalore

Super Computer Research and Training Centre, Indian Institute of Science, gave a talk on Neural Networks, March 7, 1994.

Madras

MIT Campus, Anna University, gave a talk on Neural Networks March 9, 1994.


4861 A Feb.6, 1994
Intensity (photon counts)
Geomag. Lat.
Time Hrs. (UT)