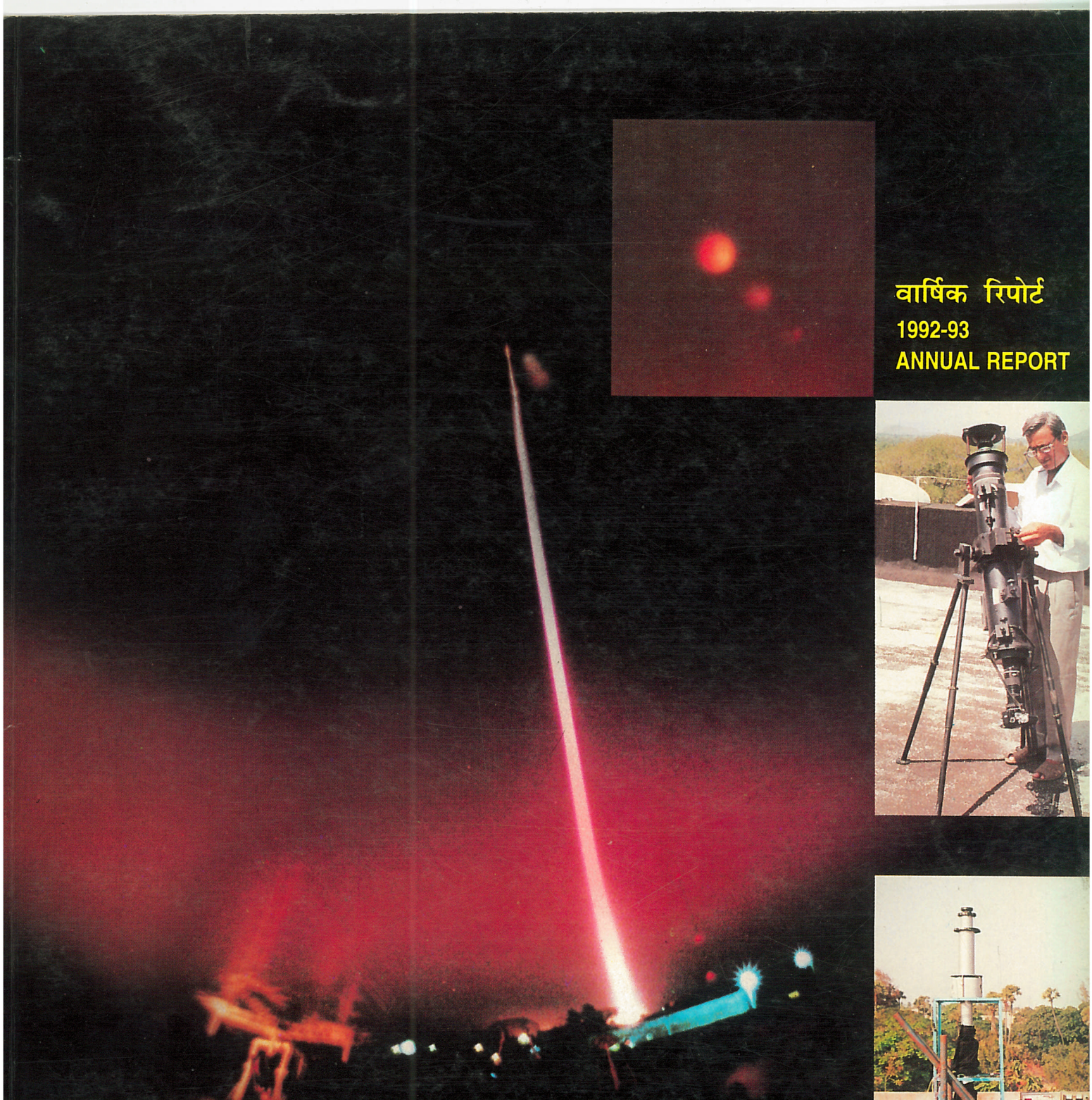

वार्षिक रिपोर्ट
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ANNUAL REPORT

भौतिक अनुसंधान प्रयोगशाला, अहमदाबाद

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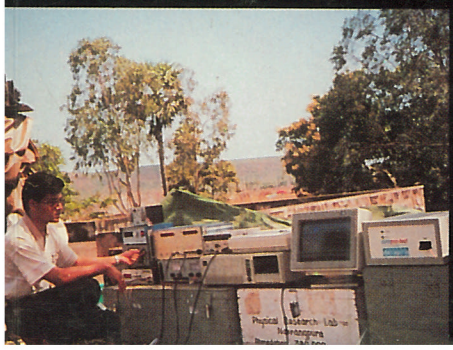

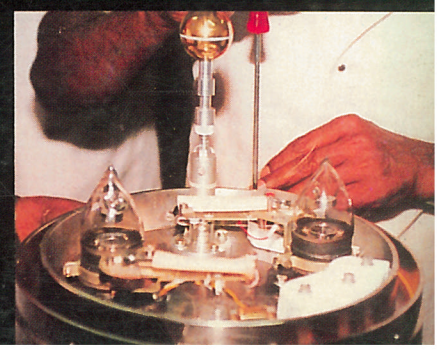

"Ionisation - Hole" rocket flight campaign conducted from SHAR on February 19, 1993.

Ba - clouds

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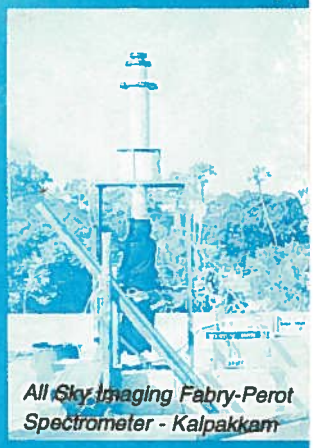
All Sky Imaging Camera - SHAR



All Sky Imaging Fabry-Perot Spectrometer - Kalpakkam

Wide angle photograph covering the rocket launch and multiple Ba - releases.

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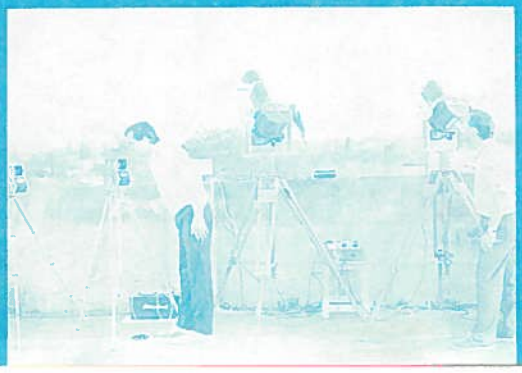
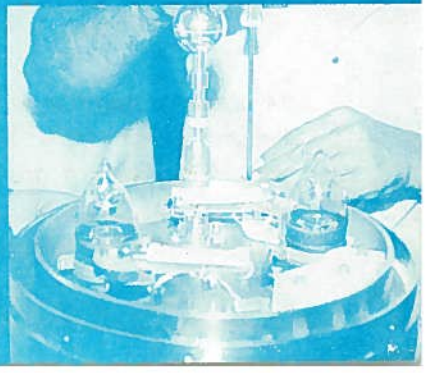
PHYSICAL RESEARCH LABORATORY, AHMEDABAD

Day Glow Photometers - Waltair

Camera Station - Kavali



Instrumented Payload - Mass Spectrometers and Langmuir Probe



Temporal sequence of Fabry-Perot fringes taken from an equatorial station Kalpakkam on February 28, 1993 using the All Sky Imaging Fabry-Perot Spectrometer.

Inner Pictures by :
D. R. Ranpura

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Introduction

The year 1992 - 93 has been a year of considerable scientific excitement at the Physical Research Laboratory (PRL). While the variety of ongoing scientific activities being carried out at PRL have continued with vigour, some new programmes and areas of activities initiated over the last couple of years have begun to yeild interesting results.

The Nd - Yag laser which is now fully operational has yeilded very useful and interesting data on the deposition in the stratosphere of aerosols thrown into the atmosphere by the Pinatubo volcanic eruption. The aerosol layer has been found to remain essentially unperturbed upto one year indicating the potentialities of such layers to induce climatic perturbations.

The "day - glow photometer", a unique world class instrument designed and fabricated by PRL scientists has enabled them, for the first time, to study the evolution of Equatorial Ionization Anomaly using ground based optical techniques.

This year also saw a highly successful campaign involving comprehensive rocket-based experiments along with a set of complementary ground-based radio and optical experiments in order to understand the role of neutral atmospheric dynamics on the initiation of equatorial spread - F. The data should also provide answers to some of the unresolved questions relating to the spread - F.

The IPS antenna array at Thaltej measuring 20,000m^2 has enabled the radio astronomy group to make a highly exciting and unique observation on July 29, 1992, when the pulsar 0950 + 08 exhibited, as recorded by the IPS array at 103 MHz, a sharp enhancement in the flux from a normal 3 Jansky (Jy) to an average flux of over 200 Jy. A similar enhancement was recorded also by the Rajkot antenna, thus confirming the genuineness of the event. A strong radio absorption in the ionosphere recorded at the same time indicates the existence of an X - ray flux associated with the increased radio flux.

By carrying out measurement on the tree rings in a 300 year old tree (Abies Pindrow) from Kashmir, PRL scientists have been able to provide evidence for the existence of the "little ice age" (cooling 4 - 5^{o}C) during the late 16th and the early 17th century. Furthermore, it has also been shown that during the last glacial maximum 18 ky ago and during 4 - 8 ky, the monsoon was weak, while between 8 - 12 ky, the monsoon was strong like at present.

Studies of interstellar microdiamonds isolated from three primitive meteorites with respect to nitrogen and noble gas isotopic compositions suggest that the magnitude of the nitrogen isotopic anomaly in them varies from one sample to another, which is contrary to previous suggestions for a rather uniform value.

Experiments to study the behaviour of charged particle motion in static magnetic fields have yielded rather astonishing results that point to the existence of "forbidden states" in the classical mechanical domain of parameters. The reason that these results are enigmatic is that classical mechanics admits a continuum of energy states as the allowed ones, and the existence of "forbidden state" is, therefore, contrary to well founded laws of classical mechanics.

One of the most interesting studies undertaken in the area of astrophysics deals with the identification and classification of large scale structure from amongst the numerous objects in the CFA survey, which enlist over 40,000 sources. Using the three parameters, namely the two angular coordinates and the radial velocity, the expectation of structures, such as "clusters" and "voids" are calculated from a random background distribution of galaxies.

A new programme involving the study of dusty plasmas has been initiated this year. This has relevance to the study of plasma processes in the planetary and cometary environments which have significant amount of dust therein.

Besides the specific achievements mentioned above relating to ongoing activities, PRL has also initiated new programmes and has acquired new systems and equipments which will form the basis

for newer activities in future centred around these systems.

A laser laboratory is being set up to carry out some sophisticated experiments in atomic and molecular physics. An excimer - laser pumped tunable dye - laser has recently been installed for the purpose.

Besides, two new experiments became operational during this year : photoabsorption cross - sections are being measured for sulphur dioxide at temperatures ranging from 200 to 400K in the incident photon wave length region 170 - 330 nm whereas work on fluorescence has just been taken up.

A programme to study the air glow and aurorae from Antarctica so as to obtain continuous data has been initiated this year. A multi - spectral day glow spectrophotometer will be employed. This is expected to give very valuable data relating to the phenomenon in question.

PRL has also acquired this year a high speed IBM computer RS6000 with two 580 Computer Servers, two 580 Time Sharing Servers and one 580 File Server with a speed of 39 MFlops each, complete with high speed graphics and a range of software packages. These will be networked with other work - stations and PCs to provide a high speed computational environment for the Laboratory.

The primary mirror for 1.2 m IR telescope at Gurushikhar is finally ready and should be installed by January 1994.

Finally, the most important ingredient for scientific excellence is the high level of scientific faculty of the institution. As senior members of the faculty retire, younger ones must be periodically added. PRL has been constantly looking for young and creative scientists to be added to the faculty. That is the only way to secure the future of a scientific institution which has to face tha challenges of the twenty first century to keep the torch burning bright.

It may be mentioned that a particle physics phenomenology group that was started about five years ago has established itself as the most active and strong group in the country. This is to be a part of the relativistic astrophysics and cosmology group that PRL had planned for. It is also planned to add a cosmologist to the existing group, so as to make the cosmology study group complete.

In view of the current concern regarding the environment and the dangerously increasing levels of pollutants in the atmosphere, there has been a stress recently on the studies of the climate in relation to the levels of the greenhouse gases and other pollutants. This has also led to the study of palaeoclimates to find out how the latter may have been affected by the levels of the greenhouse gases, such as the CO_2.

PRL scientists who have been studying palaeoclimates, atmospheric trace and greenhouse gases as well as those who have been studying monsoon dynamics, can very profitably come together to study the complex relationships and couplings among the various earth system components, namely the atmosphere and hydrosphere as also the biosphere which together determine our climatic system. A climate study group has thus been constituted which, apart from studying palaeoclimates, should ultimately coordinate with the atmospheric scientists and those working on monsoon dynamics. PRL has thus a strong potential for evolving an integrated and comprehensive climate study programme which, one hopes, will be exploited to the fullest in time to come.

(DIRECTOR)

Awards and Honours

Dr. R. Sridharan
Awarded the Hari Om Ashram Prerit Dr. Vikram Sarabhai Research Award in the field of Space Sciences for the year 1991

Shri H. S. Mazumdar
Awarded the Hari Om Ashram Prerit Dr. Vikram Sarabhai Research Award in the field of Electronics, Informatics Telematics and Automation for the year 1991

Prof. S. Krishnaswami
Elected Fellow of the National Academy of Sciences, Allahabad

Dr. Y.D. Devi
Indian Physics Association Ph.D. thesis presentation award for the year 1991 for the awardee's presentation at Bombay during the Nuclear Physics Symposium for the thesis entitled "Some Studies in the sdg Interacting Boson Model of Atomic Nuclei" .

Astronomy and Astrophysics

The scientific pursuits of the Astronomy and Astrophysics division encompass a broad spectrum ranging from phenomena occurring on the Sun, like flares, their relationship with magnetic field configurations, propagation of their effects in the interplanetary space; to processes related to stellar evolution and astrophysics of star forming regions, and energetic processes occurring in exotic objects like active galactic nuclei etc.

Solar flares are studied using narrow band Hα emission pictures of the Sun; from the solar telescope at the Fatehsagar lake observatory, Udaipur. A recent addition to the facilities there, is setting up of a multislit Littrow spectrograph to observe mass motions in prominences and mass ejections through Doppler line shifts.

The radio telescopes at Thaltej and Rajkot, primarily meant for observing solar wind velocities by monitoring the interplanetary scintillations, also proved very useful in observations related to pulsars. In an exciting observation recently made, the pulsar 0950+08 showed a sharp enhancement in the flux, from a normal ~ 3 Jansky (Jy) to over 200 Jy on July 29, 1992; as recorded both from Thaltej and Rajkot.

There is also fairly strong evidence (based on ionospheric absorption) that associated with the increased radio flux, there was an enhancement of X ray flux; which is rather surprising for this pulsar.

One of the techniques to probe the star forming regions is to understand the astrophysical processes occurring in these regions by observing emission line-profiles with high spectral resolution. The Orion H II region has been observed in [OIII] 5007 A emission, using the newly built Imaging Fabry Perot Spectrometer, from Gurushikhar. Another very interesting observation made on high resolution line-profile studies, has been with respect to rapid variability of a few minutes seen in Hα profiles of some Be stars.

In large galaxy clusters, one usually finds one or two luminous supergiant ellipticals near their centre-known as cD galaxies. Understanding radiation mechanisms prevailing in them is an interesting astrophysical problem, polarimetric observations were made for this purpose; and the observations suggest a two component model for radiation- one from the nuclear region of the galaxy and the other from the stellar component. Presence of relativistic beaming and synchrotron emission of radiation from nuclear region are inferred from polarimetric observations.

Eruption of a nova, is an explosive stellar phenomena occurring during late stages of stellar evolution. One such Nova-Herculis 1991, was studied extensively in the near infrared; and from these observations coronal emission in spectral line of [SiVI] at 1.98 μm was positively identified, as early as 17 days after eruption.

A more detailed exposition of important scientific results obtained by the division during the year is given in what follows.

Solar Physics (Udaipur Solar Observatory)

Magnetic Field Configuration in Flare Loops

H - alpha loops serve as a tool to investigate the configuration of magnetic field lines in flaring loops. Different models viz. simple dipole field model and Kopp and Pneuman (KP) reconnection models have been proposed for flare loops. Several flaring loops of May 13, 1981 and June 4, 1991 flare have been selected and reconstructed with an objective to find whether the H-alpha loops fit the dipole or KP reconnection model. It is found that some of the loops fit the dipole field lines while most of them follow the KP model. It is suggested that this disparity is due to the reason that magnetic field lines are in a sheared or non-potential configuration during the beginning of the flare which reverts to a minimum potential or unsheared configuration with time.

(N.Srivastava and A.Bhatnagar)

Criteria for Prediction of Filament Eruptions

From the study of four different cases of erupting filaments during their disk passage, it is concluded that the necessary and sufficient conditions for filament eruptions are as follows:

(1) The filament material should rest on only two feet.

(2) The ratio of the height to footpoint separation i.e. h/d should be approximately equal to 1.5.

The above conditions hold good for quiescent prominences while for the active prominences the ratio is found to be much lower.

Solar Proton Flare of November 15, 1989

A strong solar flare of 3B importance was observed on November 15, 1989 at USO. This flare was identified by GOES 7 satellite as an X3.2 importance flare. It gave rise to high speed and energetic particles of the order of 500 Mev. It also produced strong MW emission peaking at GHZ with a peak flux $>10^3$ sfu and dynamic radio bursts of type II, III and IV. Our H-alpha filtergrams were image processed on IDAS computer using image enhancement technique. The H-alpha area and relative intensity of the flare kernels and the structural variation of flare loops have been determined. The detailed study of various aspects of H-alpha flare in view of strong particles and radio emissions is in progress.

(Rajmal Jain)

Variability of Circum-solar Dust Ring

A study of the existing observations and theoretical concepts about the circum-solar dust feature have been carried out. It is shown that the dust ring is temporally variable in phase with the solar cycle - being easily observable during the minimum phase of the solar activity. The constituent of the ring must be micron sized particles and it is unlikely that there are 10 km sized boulders at 4 $R_\odot$ from the sun. It is also shown that the measurement along the coronal features such as streamers give rise to higher flux estimates.

(C.Debi Prasad)

Standard Solar Models and Inversion Techniques

Helioseismology is a new developing technique in Solar Physics for determining the internal structure and dynamics of the sun using measurements of its surface oscillations. The patterns of the motion observed in the solar atmosphere result in part from the interference of about 10^7 resonant waves in the interior. Reliable stratification information about the solar interior is obtained from these seismic waves. The observed oscillation data can be analysed in two separate ways; by model fitting and by inversion. The first method is to construct a set of solar models with different values of one or more adjustable parameters of the theory and to find the values that best fit the observations. Inversion techniques aim at extracting those aspects of the structure of the sun that are genuinely determined by the data.

The results of existing solar models are being compared to calibrate standard solar models. This information will be used to compute frequencies of five-minute oscillations and compared with the observed frequencies. Attempts are also made to invert these frequencies to obtain the sound speed and internal rotation rate in the solar interior.

(S.C.Tripathy and A.Bhatnagar)

On the Excitation Mechanism of [FeXIV] Emission Line at 5303 A in the Solar Corona Eclipse Studies)

5303 A emission line is one of the strongest in the visible spectrum of the Solar Corona. There is some debate as to the excitation mechanism for this line, with reference to relative contributions from radiative and collisional process. Careful sensitometric measurements and frame sub-

straction procedures were carried out for the white light coronal photograph and 10A coronal filtergram at 5303A acquired during 1980 eclipse, to study radial variation of line to continuum ratio at different azimuthal angles (This ratio is expected to remain constant for purely radiative excitation). From this study, following conclusions were arrived at:

i) In the inner coronal region (< 1.4 $R_\odot$) dominant excitation mechanism is collisional.

ii) In most azimuths, beyond 1.4 $R_\odot$, line intensity was too weak to be measured.

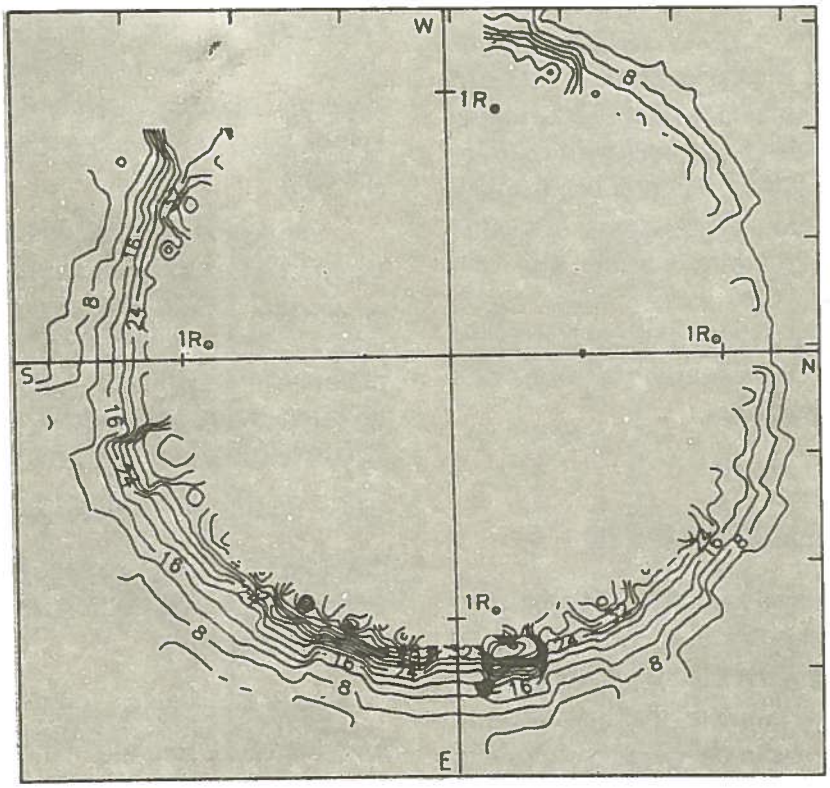
iii) However, evidence for significant contribution from radiative excitation was found beyond 1.4 $R_\odot$ at two specific azimuths. This could be indicative of particularly favourable temperature conditions to give FeXIV number densities at those locations.

Comparison of this ratio with the values calculated using model electron density (Newkirk 1961 model) show in general a good agreement. However, much steeper fall is seen in active region corona, indicating steep decline of electron density (Fig 1.1).

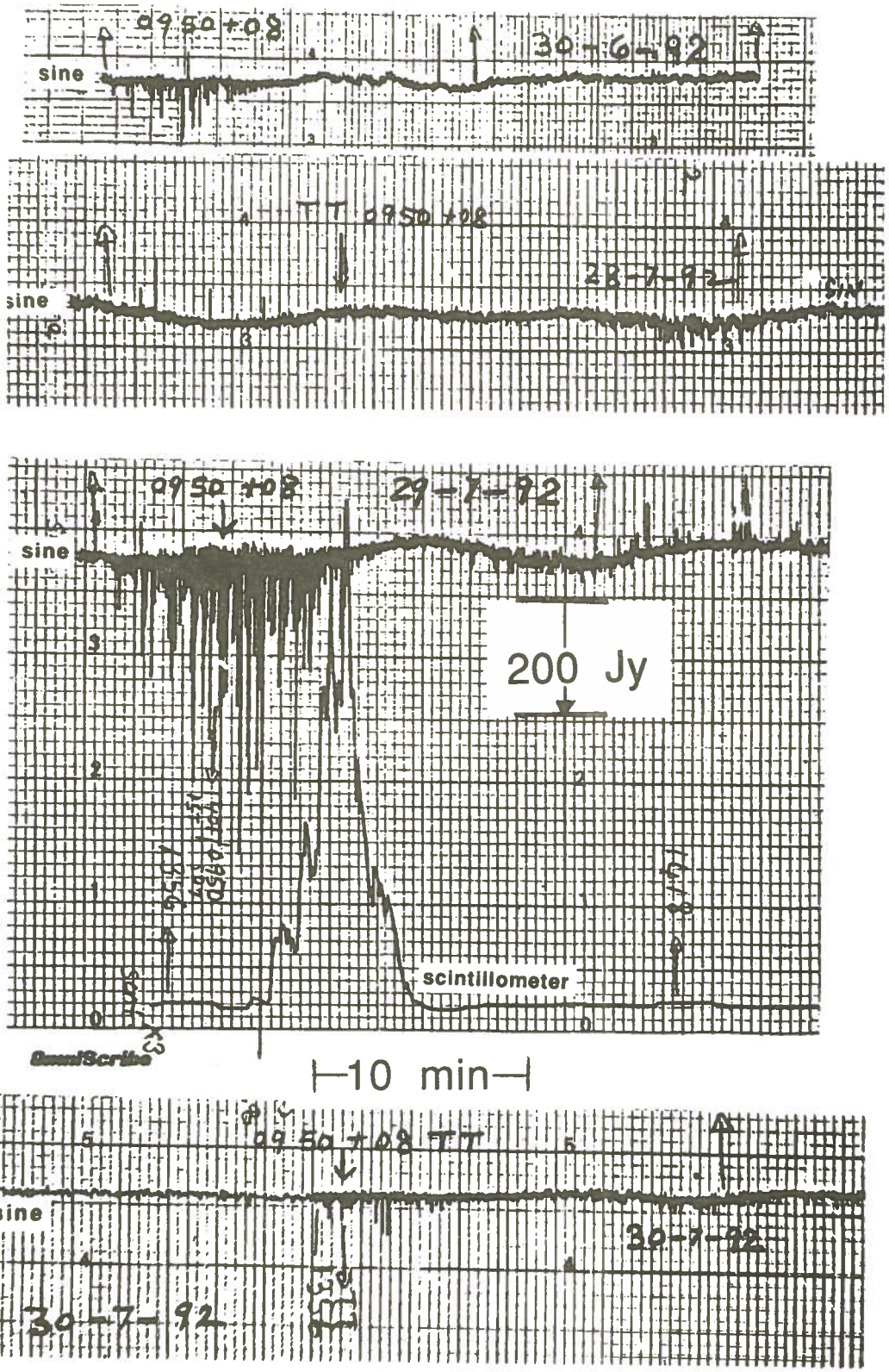
(K.P.Raju, J.N.Desai, T.Chandrasekhar and N.M.Ashok)

Radio Astronomy and Interplanetary Scintillation

Both the radio telescopes at Thaltej and Rajkot are fully operational. Regular observations of



1.1 Contour map of the λ5303 line to continuum intensity ratio observed during the 1980 total solar eclipse. Sharp gradients are observed near active regions



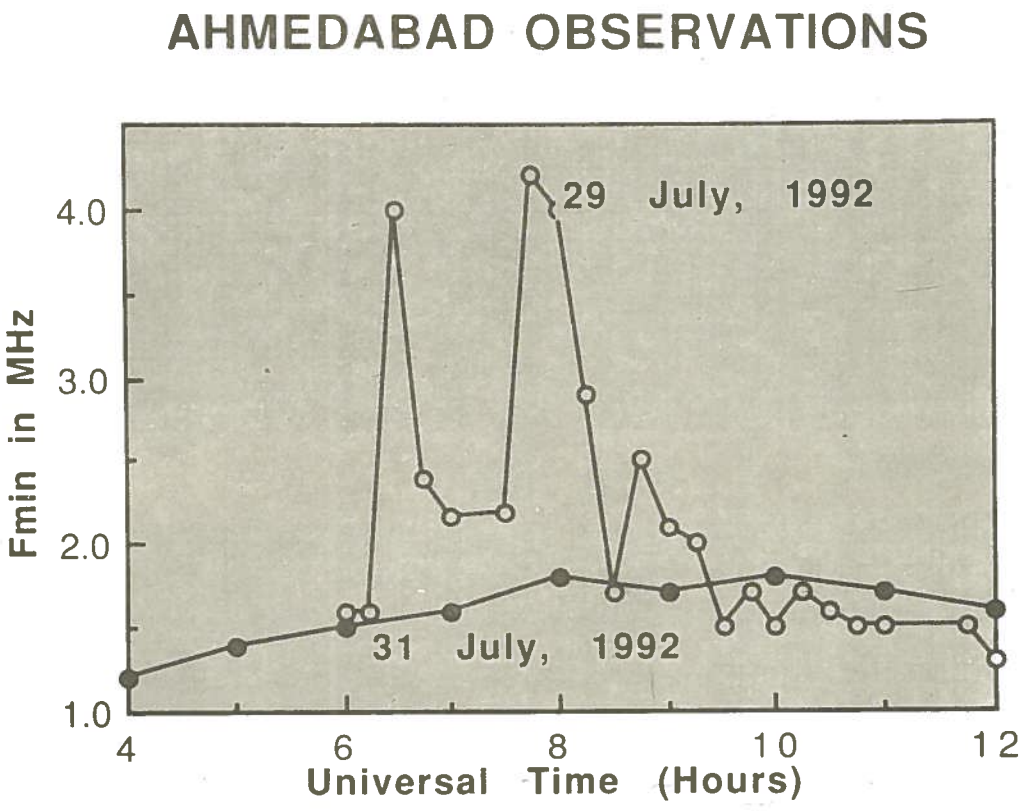
1.2 Observations of PSR 9050 + 08 on June 30 and July 28, 29 and 30, 1992 by Thaltej Radio Telescope

several radio sources have been going on. The Thaltej telescope has a collecting area of 20,000 m^2 and is now capable of receiving confusion free, all radio sources above a flux level of 4 Jy. Using this telescope we are now in the process of starting multi- receiver recording, for which, test runs with eight receivers are going on. The new system will help us in the investigations of interplanetary weather and possibly accurate forcasting of geomagnetic storms. This year, the telescopes have been used to observe a unique phenomenon from a pulsar. The observations seem to be very important for the pulsar physics. In the following paragraph a brief description of these observations, their interpretation and other investigations by this group during the year 1992-93 are outlined:

Enchancement of Flux from the Pulsar PSR 0950+08

Since the discovery of pulsar about twenty five years ago, there has been a large number of exciting events seen from several of them. PSR 0950+08 is a very interesting object which is regularly monitored (Fig. 1.2) by PRL's two radio telescopes situated at Rajkot and Thaltej. The pulsar has flux of about 3 Jy and hence it normally remains within the background noise, however Thaltej telescope being more sensitive, sometimes, a few pulses are recorded.

On July 29, 1992, this pulsar suddenly gave a very large outburst of energy and this was recorded by both radio telescopes simul-



1.3 Temporal variation of "f_{min}" on July 29 and 31, 1992 by Ahmedabad Ionosonde

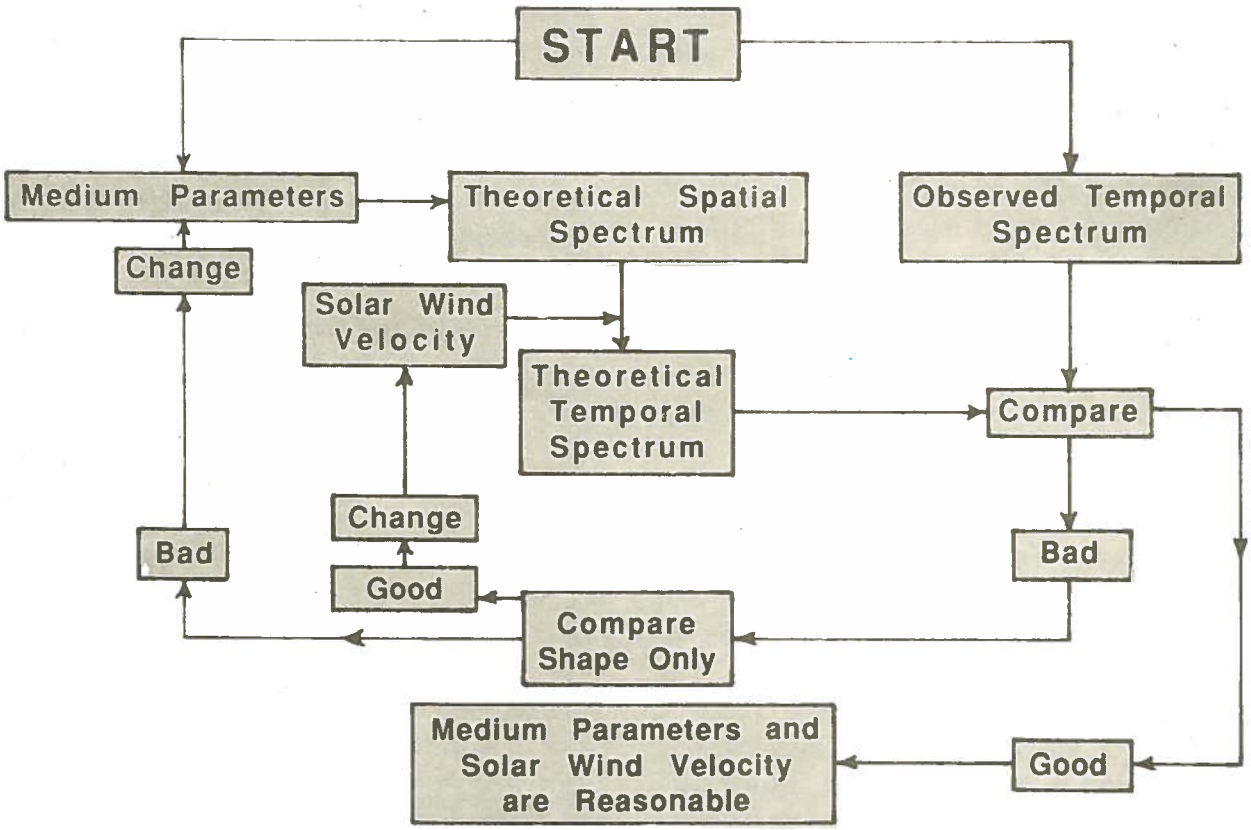
taneously. The cross-correlation analysis of both these observations showed a very high degree of correlation. The cross-correlogram and the power spectra showed that large number of pulses remained unscattered by the inter-planetary medium during their passage.

The average flux of the pulsar during this event was ~ 246 Jy (which is about 80 times the normal flux) and several pulses exceeded 850 Jy. The enchancement of the pulsar flux is very large and is seen simultaneously by both the telescopes separated by 200 kms. Moreover no enhancement was seen in any other IPS sources around the pulsar burst time. This enhancement was seen only on July 29, 1992. Preliminary analysis indicates that the burst energy was released at the source and may not be due to the propagation effect.

(M.R.Deshpande, H.O.Vats, P.Janardhan, A.D.Bobra, C.R.Shah and S.L.Kayasth)

Terrestrial Effects of PSR 0950+08

The investigations of PSR 0950+08 during the enhancement event on July 29, 1992 brought out another interesting feature of this pulsar. The pulsar 0950+08 is a relatively older one (~1.6 x 10^7 years old) and it is not a known X-ray emitter. However, on July 29, 1992 there exists an indirect evidence showing a very intense X-ray emission by the pulsar. This evidence is seen (Fig. 1.3) in the ionospheric sounding experiment (just 6 kilometers away from the tele-



1.4 A scheme for the estimation of Solar Wind by single station IPS observations

scope). This effect has produced three very distinct and prominent peaks in " f_{min}". Such a temporal variation of "f_{min}" is seen only during an intense solar X-ray flare. On 29 July, 1992 there were not even mild solar flares. On the contrary, the sun on this day was reported to be unusually quiet. Thus the required X-ray flux to produce the observed effect in "f_{min}" seems to be from the active pulsar.

The calculations indicate the possibility that PSR 0950+08 accreted a comet like object during this event and produced a burst at radio (seen directly) as well at X-ray wavelengths (seen indirectly). Further theoretical and observational investigations of this pulsar and also other pulsars are necessary to understand these results.

(H.O.Vats, Harish Chandra, M.R.Deshpande, G.D.Vyas, Bharti Bhatt and C.R.Shah)

Comparison of Single-site Interplanetary Scintillation Solar Wind Speed Structure with Coronal Features

Interplanetary Scintillation (IPS) Observations were made during the period 1984-1990 using a single radio telescope at 103 MHz situated at Thaltej (Ahmedabad). Solar wind speeds were estimated using a recently developed method (Fig. 1.4)based on matching the observed IPS spectra with model solar wind spectra for Kolmogorov turbulence. The best-fit speeds derived are traced back to a source surface, and average velocity maps are made for each year, averaging over a number of Carrington rotations. It is found that the resulting single-site large-scale IPS speed structure agrees well with that derived from 3-site observations from earlier workers. The IPS speed structure during this period was compared with other coronal features. Nearly 85% of the observed high-speed regions were associated with coronal holes. At solar minimum in 1986 a quasi-sinusoidal narrow belt of slow solar wind was observed which matched well with the neutral line structure of the solar magnetic field and the belt of active centers. Near solar maximum in 1990 the speed structure was chaotic, similar to that of the neutral line, with low speed regions appearing all over the source surface.

(H.O.Vats, P.Janardhan, S.K.Alurkar, K.J.Shah, U.K.Modi and A.H.Desai)

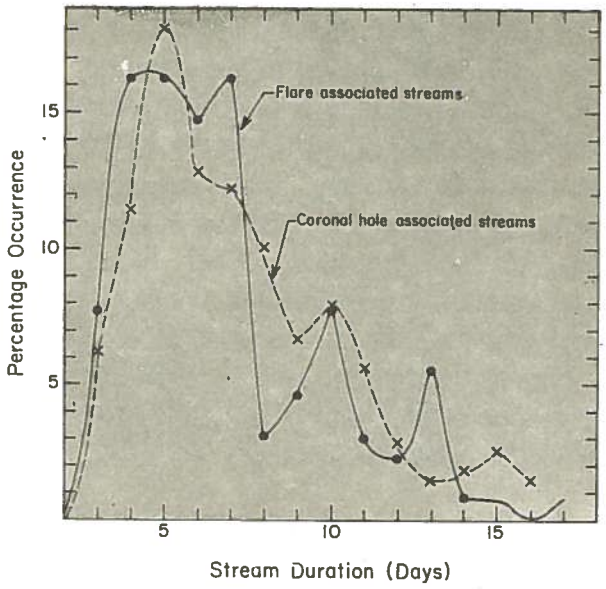
Possible Contribution of a Solar Transient to Enhanced Scintillation of a Quasar

Observations of the quasar 2314+038 were carried out during 16-21 December, 1985 at a solar elongation (ε) around 85^{o} , when the plasma tail of comet Halley swept in front of it. These observations have shown a two-fold increase in scintillation index (m) as compared to the expected levels of scintillation for the source, computed using the well-known RKH model. Spacecraft data and the geomagnetic indices available during the period show that a shock-front had reached the earth on the 18 December, the day when maximum increase in scintillation was recorded. The possible contribution of such a shock-front to the enhancement has been shown to be not greater than 15 percent. Hence, the major contribution to the enhancement came from the plasma tail of a comet.

(P.Janardhan, S.K.Alurkar and A.K.Sharma)

Power Spectral Analysis of Enhanced Scintillation of Quasar 3C459 due to Comet Halley

The radio source 2314 + 038 (3C459) showed enhanced scintillations on three days at a solar elongation of about 90^{o} as the plasma tail of Halley's Comet swept across it during 16-21 December 1985. If we assume that the plasma velocities in the tail were not constant everywhere, but increased linearly from about 50 kms^{-1} at the tail axis to the normal average solar wind velocity of 400 kms^{-1} at the edges where the tail merged with the solar wind, a power spectral analysis of the scintillations shows two ranges of the rms electron density variation ΔN and scale size



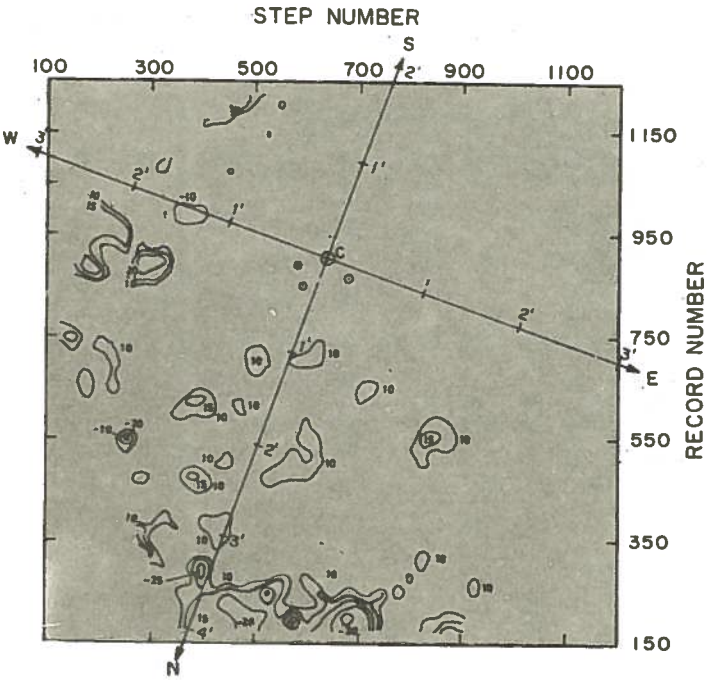
1.5 Distribution of stream duration for flare and coronal hole associated high speed streams.

"a." In particular, there is a fine scale zone near the axis where "a " is in the range 9 to 27 km and ΔN in the range 2 to 5 cm^{-3} and a zone near the edges with "a "and ΔN in the ranges 100 to 265 km and 0.4 to 0.8 cm^{-3} respectively. The assumption of a single velocity of 100 kms^{-1} throughout the tail shows similar fine scales near 18 km at the axis to about 70 km at the edges, corresponding to ΔN of 3.3 and 0.85 cm^{-3} respectively. A comparison with the results obtained by Australian group shows that there is no radial variation of ΔN. The tail-lag is seen to play a crucial role in determining the correct occulting geometry and the path of the source through the tail.

(P.Janardhan, S.K.Alurkar and A.D.Bobra)

High Speed Streams

Investigations of high speed streams associated with solar flares and coronal holes were carried out. Two kinds of fast streams, namely, solar flare and coronal hole associated streams are investigated for their characteristics and as causative source of geomagnetic disturbances. The coronal hole associated streams are known to be twice more abundant than the solar flare associated streams. The occurrence probability of the peak observed velocity and duration of these events are comparable for coronal hole as well as solar flare associated streams. It is also found for both the type of streams that average enhanced Ap during the events increases as the average peak velocity during the events, but the rate of increase for flare associated streams is about 2.7 times higher than that of coronal hole associated streams. This is perhaps due to plasmoid nature of flare streams. On the other hand it is found that the coronal hole associated streams produce longer duration geomagnetic disturbances, even



1.6 Contour map of relative line of sight velocities (referred to mean zero) in λ6731 [SII] in Orion HII region. Trapezium stars are marked. High velocity regions in north- west and especially towards north direction are noticeable

if the coronal hole and solar flare associated streams have comparable duration and speed in general (Fig. 1.5).

(H.O.Vats, K.J.Shah and U.K.Modi)

Optical and Infrared Astronomy

Imaging Polarimetry of Comet Austin

Polari- metric images of Comet Austin taken on photographic emulsion were digitized using PDS machine at IIA. The polarization map for April 30 does not show structures as are seen in comet Halley. There are regions of high and low polarization nearly symmetrically distributed about the nucleus. The overall polarization is low. This may be due to the images taken in white light.

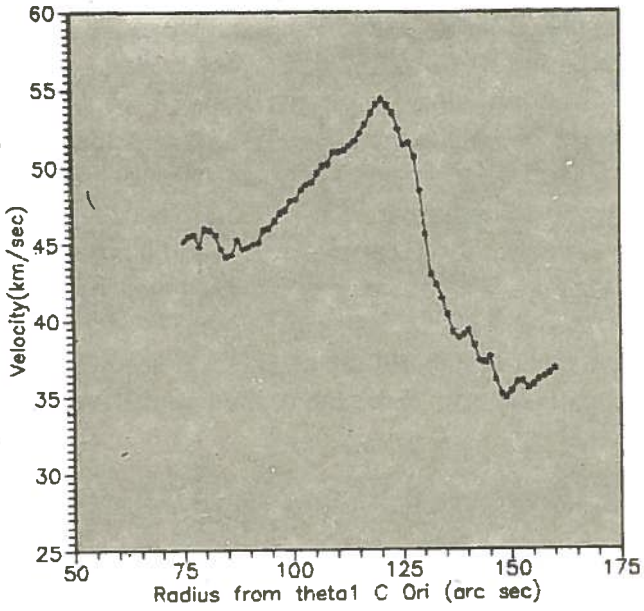
(U.C.Joshi, A.K.Sen and M.R.Deshpande)

Velocity Field Structure in Orion Nebula

The Orion nebula (M42, NGC 1976) is the closest HII region located at a distance of 460 parsecs and embedded with multiple young stellar complexes θ^1Ori (the Trapezium stars) and θ^2Ori, presenting a very good opportunity to study the astrophysical processes in HII regions related to star formation. Past studies by several workers have indicated a highly complex velocity structure surrounding the Trapezium. We have recently carried out high resolution imaging observations of this region in [SII] 6731A and [OIII] 5007A emission lines.

Observations in emission of ionized Sulpher at 6731 A : These observations were carried out using a Fabry Perot Camera with an image intensifier. [SII] emission is a useful probe of the HI-HII interface as the emission extends slightly beyond the visible nebula. Interferogram which

1.7 Iso - velocity contour map obtained from [OIII] 5007 A interferograms. θ^1C and θ^2A,B represent the stellar complexes θ^1Ori and θ^2Ori



1.8 Radial scan perpendicular to the Orion 'bar' ionization front

was taken covering 6'x6' field show that emission is more extended in the region NW of Trapezium stars. Line of sight velocities were calculated for 1500 points in this region. The contour map for relative velocities $|V| > 10$ kms is shown in the figure 1.6. Large relative velocities ~ 30 kms^{-1} are seen at the nebular boundaries. These could either be due to outflow associated with ionization fronts which are directed towards the observer; or could be jets emanating from embedded stars at the formative stage.

(K.P.Raju, C.Debi Prasad, L.Misra, and J.N.Desai)

Observations in emission of doubly ionized Oxygen at 5007 A : These observations were made with the newly constructed Imaging Fabry-Perot Spectrometer (IFPS) on 35 cm C-14 telescope from Gurushikhar, Mt.Abu. A total of 32 interferograms were taken covering most of the regions across the nebula in an area of 11x11 $arcmin^2$. The important results of this study are as follows:

1) The iso-velocity contour map (Fig. 1.7)constructed from radial velocities derived at more than 2000 points reveals several circularly symmetric, localised high velocity structures, indicative of winds from young stellar objects (as inferred from the infrared images), superposed on a general velocity field showing a decreasing trend outwards of the Trapezium cluster. The general flow pattern is in accordance with the theoretical models for the velocity flow evolution in HII regions.

2) One very interesting feature that has emerged out of this study is that the contour map shows a possible global quasi-symmetric structure centred almost on the BN-KL complex close to the Trapezium stars where repeated bursts of star formation have been going on. Further analysis for understanding this feature is being done.

3) Our results also revealed yet another interesting and important feature namely the high velocity flow across the ionization front coming from the central Trapezium star θ^1Ori C. This is perhaps for the first time that a velocity profile across an ionization shock front has been obtained (Fig. 1.8). The velocity profile is in perfect accordance with the density profile obtained elsewhere and agrees very well with the physical conditions across isothermal shock fronts.

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

Rapid Variability of Emission Line Profiles in Be Stars

A number of Be stars are known to show rapid variability in their emission line profiles. Possible physical processes responsible for such variability are : rotation, non-radial pulsations and chaotic magnetic fields. In order to understand physics of the variability in emission lines it is essential to determine its periodicity or the lack of it. High-resolution ($\lambda / \delta\lambda = 10^4$) Fabry-Perot Spectrometric observations have been initiated at the Japal Rangapur Observatory in collaboration with the Astronomy Department, Osmania University, Hyderabad. Observations of Hα emission line have been made on four Be stars at the time of their active phase during December 1992 and February 1993. Several numbers of high quality profiles of Hα emission line have been obtained from these stars some of which have a known history of episodic variability. All the stars viz. γ Cas, λ Eri, ω CMa and χ Dra, showed variability in the emission line shapes and the former two stars showed episodic, aperiodic behaviour with time scales of the order of a minute which is perhaps the shortest timescale of variability ever reported in Be stars. The implications of our results on the possible physical mechanisms are being worked out.

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

High Angular Resolution by Lunar Occultations at 2.2 microns

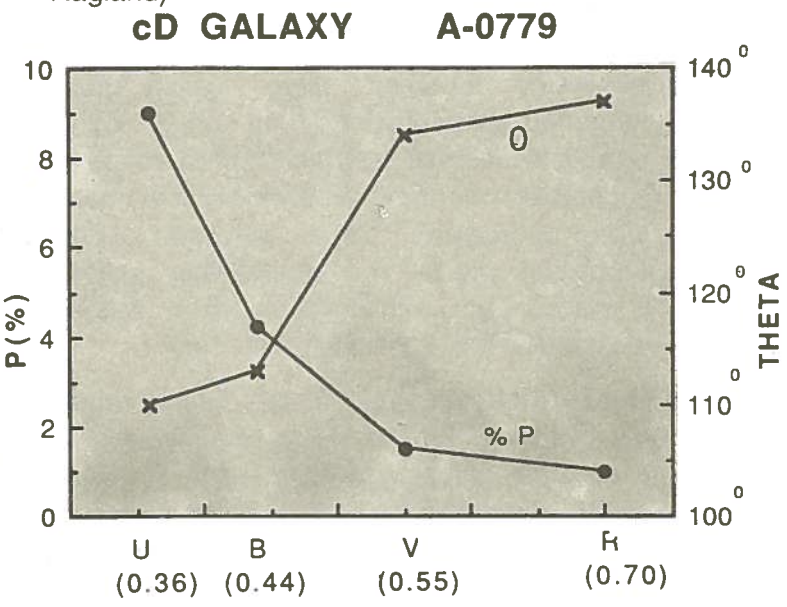
Lunar occultation of stars and star forming regions is a novel approach to High Angular Resolution distinctly different from other techniques of optical interferometry like Long Base Line Interferometry (LBI). The technique makes use of the fact that as the moon moves relative to the stars, its sharp limb serves as an effective diffraction straight edge for the light from .the star undergoing occultation. One dimensional source structure at the level of a few milli arc seconds can be determined from the detailed study of the observed diffraction pattern.

In the Infrared region at 2.2 microns (K band) due to the greatly reduced scattered background radiation from the moonlit sky, it is possible to achieve much better S/N of the diffraction fringes compared to the visible region. The thermal emission from the moon's limb itself is also not significant in the K band. At PRL we have taken up a program of High Angular resolution of stars and star forming regions by observing lunar occultations in the Infrared at 2.2 μm. Accurate angular diameter measurements help in comparing photometric observations with model atmospheric fluxes and in quantifying the amount of IR excess and hence amount of circumstellar matter. Five occultations have been successfully observed with our instruments at Kavalur at 2.2 μm, three of them in the past year. A new IR detector system with a smaller time constant specially ordered for occultation work is now in operation. A special mention must be made of the successful observation at 2.2 microns during daytime (~ 1430 hrs IST) on 27 January1993 of a carbon star TX PSc. The observations were carried out with the 14 inch Celestron telescope riding on the main telescope drive system at Gurushikhar. This observation opens up interesting possibilities of regular daytime observing atleast for occultations with the Gurushikhar 1.2 m telescope when it is back in operation.

In order to determine the one dimensional source structure from the observed occultation pattern it is necessary, in the detailed analysis, to take into account the finite time constant of the detector system, optical bandwidth of the filter used, the telescope aperture and also scintillation noise. An occultation data analysis package incorporating the above features has recently been developed and applied to the TX PSc data.

TX Piscium (SAO 128374) is a N type carbon star. CO (J=1-0) 2.6 mm emission is present and IRAS data shows far Infrared excess attributable to emission from cool circumstellar carbon grains at 125 K. Our lunar occultation measurements lead to a limb darkened diameter of $\theta = 7.6 \pm 1$ milliarcseconds. No other near Infrared occultation diameter is available for this star so far. An effective temperature of 3080 ± 150 K for TX Psc has also been deduced from flux and angular diameter measurements.

(T.Chandra Sekhar, N.M.Ashok and Sam Ragland)

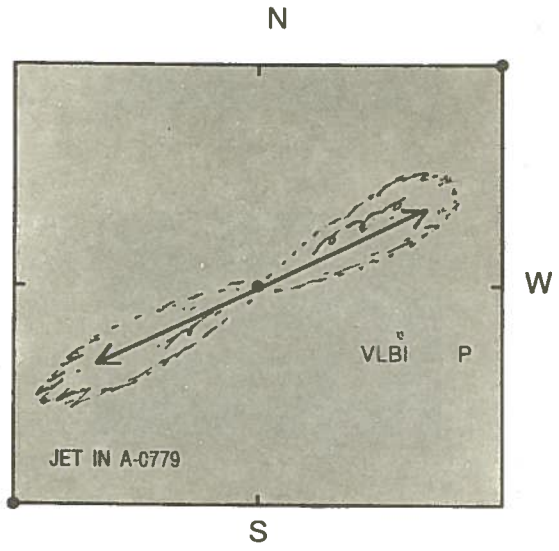


1.9 Percent polarization (P) and position angle (θ) observations with wavelength for a cD galaxy A-0779. Note the high degree of (P) in U band and a bimodal distribution in θ

Near Infrared Coronal Line Emission in Nova Herculis 1991

A nova is an explosive astrophysical phenomenon happening in a binary system in which one of the components is a white dwarf. It is brought about by thermonuclear runaway on the degenerate surface layer of the white dwarf. An unusually bright and fast nova occurred in constellation Herculis in March 1991 which was extensively observed in the Infrared region by PRL scientists from the IR observatory at Gurushikhar, Mt.Abu. An interesting aspect of the study was the detection of an emission line at 1.98 ± 0.02 μm in the spectrum of the nova. The line was detected as early as day 17 after the nova explosion. The spectral line has been identified as forbidden coronal emission due to [Si VI] ion. The presence of this highly ionized species requires large energy inputs to the region to sustain the population of high lying states against adiabatic cooling. Interestingly Nova Her 1991 was also the first ever nova to be detected in the X-ray region by ROSAT at a very early phase. The high temperature zone needed for X-ray emission also constitutes a favourable environment for the production of highly ionized species like [Si VI]. The strength estimated from our observations of the [Si VI] IR emission of $(3.5 \pm 0.6) \times 10^{-10}$ erg/cm^2/s requires a mass density of 1.7×10^{-15} g/cm^3 which is above critical density for dust formation and is thus consistent with the scenario of dust formation by the time coronal emission manifested itself. The X-ray observations are also consistent with the picture of novae ejecta adding substantially to a preexisting material and reaching a final density value of 2×10^{-15} g/cm^3 by the time the dust formation process was complete. The conclusion is that the IR coronal line emission could arise from the same region at the outer periphery of the dust formation zone from where X-ray emission originated early in the nova evolution.

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



1.10 VLBI map for A-0779 : Jet oriented at angle of 110° which exactly coincides with polarization angle in U band

Active Nuclei Galaxies

Study of cD galaxies : A distinct feature of large clusters of galaxies is the presence of one or two highly luminous supergiant elliptical galaxies near the centres of the clusters. These galaxies, known as cD galaxies are most luminous galaxies in the universe and also largest, also have extended amorphous stellar envelope. Since cD galaxies give out large amount of energy it is worthwhile to establish the radiation mechanism and physical processes leading to the excess energy generation.

With the above goal in mind, observations were made of a cD galaxy A-0779 in the Abell cluster. These observations were made on VBT using PRL polarimeter, using UBV and R filters. The results are shown in (Fig. 1.9). Surprisingly large amount of polarization (about 9 ± 0.1 percent) was observed in the ultraviolet which decreased to 1percent in the Red. The position angle in Ultraviolet and Blue was about $110^\circ \pm 1^\circ$, which suddenly increased to about $135^\circ \pm 1^\circ$ in Visual and Red. The position angle in ultraviolet exactly

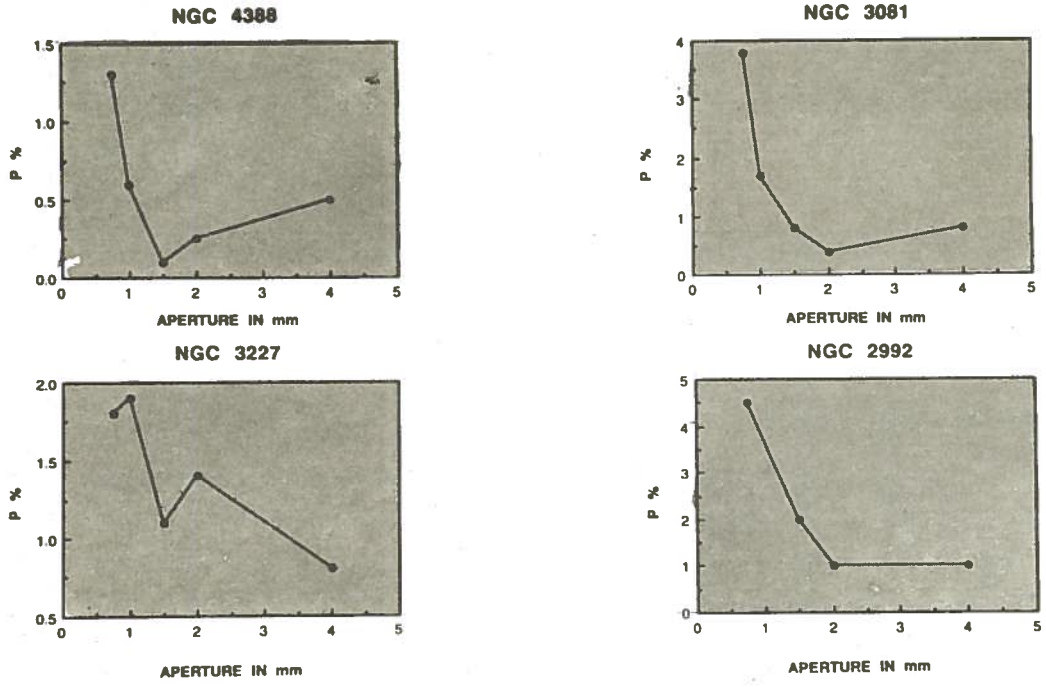
coincides with the jet direction as observed by VLBI studies (Fig. 1.10).

The high degree polarization in ultraviolet and bimodal distribution position angle can be explained in terms of two component model, one the contribution from the nucleus and the other from the galaxy itself. The high degree of polarization and the coincidence of position angle in ultraviolet with the radio jet suggests the presence of relativistic beaming and synchrotron radiation from the nucleus. These are the first observations of polarization from a cD galaxy and we hope to observe many more galaxies in the next year. Also observations are planned with various apertures to assess the contribution of galaxy vis-a-vis nucleus.

In conclusion we report the detection of non-thermal radiation from the nucleus of a cD galaxy A-0779.

Study of Seyfert galaxies : Seyfert galaxies which form a subclass of Active galaxies are characterised by bright nucleus, with most of their energy being radiated in the Infrared region. Some of the Seyfert (type 2)show broad permitted emission lines, tens of thousand km/sec in width. Also there is evidence of nonthermal radiation in some Seyfert galaxies. We have detected the nonthermal radiation from four Seyfert galaxies through a new approach described in the next section. We propose to observe several Seyfert galaxies next year from 1.2 m IR telescope from Gurushikhar, Mt.Abu.

The observations were made on VBT (2.3 m aperture) at Kavalur with PRL polarimeter using different apertures. If the radiation from the nuclei of Seyfert galaxies is of thermal origin, one expects blackbody distribution with low or no polarization. On the other hand if the radiation is of synchrotron origin one expects large degree of polarization, but in actual practice we observe the mixture of the above two radiations. The thermal



1.11 The figure shows polarisation in Seyfert Galaxies for different apertures. As the aperture is decreased, the relative contribution from the galaxy, compared, to nucleus decreases. This shows enhancement and polarization indicating the generation of Synchrotron radiation from the nuclei of the galaxies.

radiation usually dominates the entire galaxy and is produced due to stellar light and the light scattered by the atoms, molecules and dust in the galaxy. On the other hand the synchrotron radiation mainly originates from the nucleus. To decide which of the two mechanisms prevail it is important to do polarization measurements with different apertures. If one observes increase in polarization with the decrease in aperture then synchrotron radiation mechanism is operative. On the other hand if there is not much change in polarization with aperture variation one expects thermal radiation to dominate. With above facts in mind we have taken up the programme of Seyfert galaxies. In the galaxies NGC 2992, NGC 3081, NGC 3227 and NGC 4388 we have detected a strong evidence for synchrotron radiation. Fig. 1.11 shows variation of percentage polarization (P) with aperture. (On VBT, 1 mm aperture corresponds to 6.5 arc sec in the sky). One can clearly see that the degree of polarization decreases with the increase in aperture size. The degree of polarization is about 4 percent in case of NGC 3081 and 2992 (error ± 0.1 percent) for 0.5 mm aperture. Such a high degree of polarization cannot be explained without the help of synchrotron mechanism. We propose to undertake an exhaustive work on several Seyfert galaxies with photometric observations to substract the galactic contributions, once our 1.2 m telescope at Gurushikhar is operational.

(U.C.Joshi and M.R.Deshpande)

Quasar-Galaxy interactions : A possible mechanisms of a formation of cD-galaxies and gravitational lenses : Tidal effects of disruption and merger of a massive perturber-quasar on a galaxy cluster have been studied by computer simulations using Aarseth's N-BODY 2 code. The model consists of a spherical N-body galaxy cluster and a point-mass perturber. A wide range of the initial conditions (the ratios of masses of the objects, virial coefficient q of N-body system, pericentric distances and eccentricities of the orbit) have been used.

It is shown, for a small pericentric distances, parabolic orbits and values of virial coefficients $q > 0.5$, collisions of objects can result a merger of them and a formation of products with properties of the cD-galaxies or gravitational lenses. This work was done in collaboration with P.M.S. Namboodiri of IIA.

(J.Anosova and M.R.Deshpande)

Spheres of Regular and Chaotic Motions in the Three- and N- Body systems

The character of basic Newtonian regular and chaotic motions of the bodies inside triple and $N > 3$-body systems of stars and galaxies is described. These motions were studied by various authors by computer simulations. It is shown that, in general, the basic motions of the bodies in both types of systems are same. In the clusters we observe roughly a superposition of motions of singular bodies as well as the different types of the weak and strong two- and three-body interactions.

Therefore, one may in detail study the interactions of the bodies in the N-body systems by means of the computer simulations in the frameworks of the isolating general three-body problem. Then it's required to distinguish the regular and irregular fields in the clusters or, on other words, to find the "fine structure" of ones. It is also, necessary to consider a representative samples of initial conditions for triples with positive and negative total energy.

Different types of criteria of isolation of subsystems inside the clusters as well as multiples and clusters in the general field of stars and galaxies are discussed. New dynamical criteria of isolation of triples and multiples in the field are developed.

A classification of close triple Newtonian interactions is given for equal-mass bodies as well as for selected sets of unequal- mass components. The regions of initial conditions for strong three-

body interactions that do or do not lead to immediate escape from triples with equal-mass components are found.

(J.Anosova)

Astrophysical Investigations with IR Polarimetry

This is a DST funded project. Under this project Infrared Polarimeter is being designed and fabricated in PRL. Control electronics circuitry has been tested and found to work satisfactorily. Integration of the system is in progress and is expected to be complete by July 1993. Observations are planned during October 1993 when our 1.2 meter telescope is expected to be operational.

(U. C. Joshi)

An Innovative Sidereal Drive Unit for 1m class Astronomical Telescopes

An innovative, and inexpensive sidereal tracking drive unit (SDU) has been constructed for the 1m or larger class of astronomical telescopes. The SDU is tunable and has a very highly stable and undistorted sinusoidal wave shape. The SDU consists mainly of a variable drift-free drive rate generator and a distortion-free, low-cost power amplifier. The SDU has been successfully installed for the accurate tracking of the 1.2 m telescope at the Japal-Rangpur Observatory (JRO) near Hyderabad and tracking accuracies of less than a few arc seconds in sky are achieved in 60 minutes of observation time. The unit can also be used in negative feed-back mode to correct any errors in the tracking system.

(B.G.Anandarao, K.S.B.Manian and F.M.Pathan).

Special Optical Coatings for Astronomical Observations

Multiband astronomical observations frequently need multilayer dielectric optical coatings with specially designed band shapes for transmittance and reflectance (dichroic coatings). For such a purpose three-layer of R coatings on glass, using a layer each of CeF, Zns, and MgF_2 have been developed. These coatings are much more efficient than our earlier single layer coatings; the total reflectance from both the surfaces of a substate having these AR coatings, for example, is about (or less than) 0.1 percent at the design wavelength, and it remains below 1% over a range of about 1000 A in the visible spectrum, as compared to the minimum reflectance of about 2.6% at a single wavelength in the case of a single layer AR coating.

To isolate narrow band pass at a desired wavelength filters with FWHM of 10A have also been fabricated inhouse. Peak transmittance is 19%. Stability is being monitored.

Feasibility of making Fabry-Perot type filters for low energy free electrons has also been studied.

(S.D. Rawat)

List of Papers Published During 1992-93

1. B.G. Anandarao, S.R. Pottasch, P. Seema and D.B. Vaidya, "Circumstellar Dust in Mira Variables and the Pulsational Mass Loss, in Cool Stars, Stellar Systems and the Sun",Ed. M.S.Giampapa and J.A.Bookbinder, Astr. Soc. Pacific Conf.Ser., **26**, 474 (1992).
2. A.Bhatnagar, A.Ambastha and N.Srivastava, "Filament Euptions Flaring Arches and Eruptive Flares" in "Eruptive Solar Flares" ed. Svestka, Z. et al. p.59, Publ. Springer Verlag (1992).
3. T.Chandrasekhar, N.M.Ashok, and Sam Ragland, "A High speed Photometer in the optical region for lunar occultation studies".J.Astrophys. Astr. **13**, 195 (1992).
4. T.Chandrasekhar, N.M.Ashok, Sam Ragland, "Near Infrared Coronal line Emissio ı i Nova Herculis 1991".J. Astrophys. Astr. **14**, 7 (1993).
5. P.Janardhan and S.K.Alurkar "Possible contribution of a solar transient to enhanced scintillation of a quasar", Earth, Moon and Planets **58**, 31 (1992).
6. U.C.Joshi, A.K.Sen, M.R.Deshpande and J.S.Chauhan 'Photopolarimetric Studies of Comet Austin", J.Astrophys. and Astronomy **13**, 267 (1992).

7. P.Seema, B.G.Anandarao, D.P.K.Banerjee, N.S.Jog and R.T.Patel, A Photon-counting Imaging Fabry-Perot Spectrometer for kinematic studies in extended astronomical objects", Publ. Astron. Soc. Pacific, **104**, 1091 (1992).

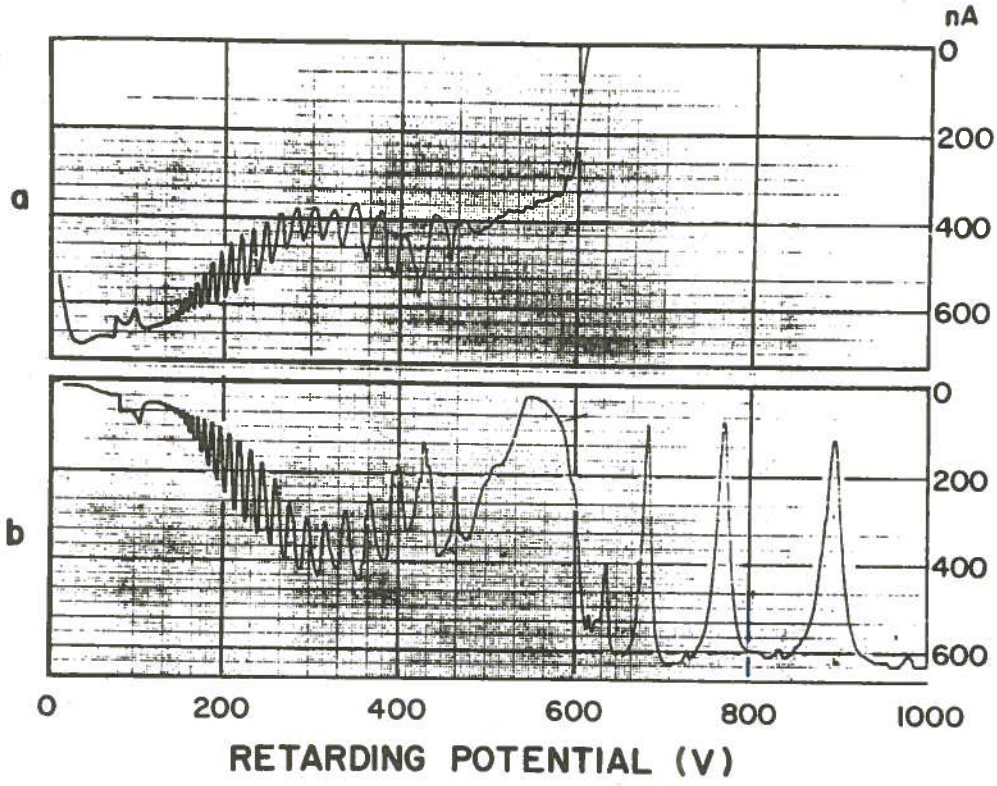
8. Hari Om Vats, "Flare-associated high-speed solar plasma streams", Solar Phys. **138**, 379 (1992).

9. Hari Om Vats, "Solar Wind and Geomagnetic Activity" Geological Society of India Memoir **24**, 365 (1992).

Basic Physics Laboratory

We had earlier reported about our experimental observations of the "discrete energy states", belonging to the system of charged particles moving in a magnetic field. The observations were made in a classical mechanical domain and were found to be in conformity with a quantum-like formalism, clearly nonquantal in nature, given by one of the authors (R.K.Varma). The present experiments carried out on the same machine have given important results in understanding the phenomenon.

An electron gun is used to inject a low current ($\leq 0.1\mu A$) electron beam into a stainless steel chamber (27cm dia and 3.1m long) evacuated to $5x10^{-7}$ torr. An axial magnetic field uniform to within 0.1% is produced in the chamber by a set of 35 coils. The electron gun is situated at one end of the vacuum chamber injecting electrons almost parallel to the magnetic field, while a collector plate with a grid positioned 1cm in front of it, is placed at the other end. The collector plate - grid assembly can be moved along the axis of the



1.12 A comparison of the plate and anode current profiles as the grid potential is varied. (Beam Energy = 600 eV, gun-grid distance = 19 cms, B = 177 Gs)

chamber and the grid can be raised to any desired potential during the course of the experiment.

The gun is switched on in a steady continuous operation with a certain electron energy E. When the potential on the grid is swept from zero to a large value $-\Phi_{max}$ the plate current ought to decrease monotonically to zero, as one would expect from the classical mechanical equations of motion. We have reported that instead of the expected monotonic response the current collected by the plate exhibits an oscillatory behaviour showing peaks and dips, which we had interpreted as "allowed" and "forbidden" energy states of the system. These states were found to fit well into a theoretical relationship

$$E_j = \frac{1}{2} m \left(\frac{3\Omega L}{2\pi}\right)^2 / \left(j + \frac{1}{4} - \frac{\varphi}{2\pi}\right)$$

which follows from the above referred wave formalism.

The question as to what happens to the missing current corresponding to the forbidden states while the electron gun is in a continuous operation had remained unattended. To answer this question we measured the currents flowing to the ground both from the anode and the cathode. The anode current plots obtained for various gun to collector plate distances are found to exhibit oscillations which are out of phase with the measured plate current as the grid potential is swept from $-\Phi_{max}$ to zero. This leads us to conclude that the missing current corresponding to the forbidden state is actually forced to find its way as the anode current flowing to the ground. The cathode current, on the other hand, shows no oscillations in the present case where the grid

Table I

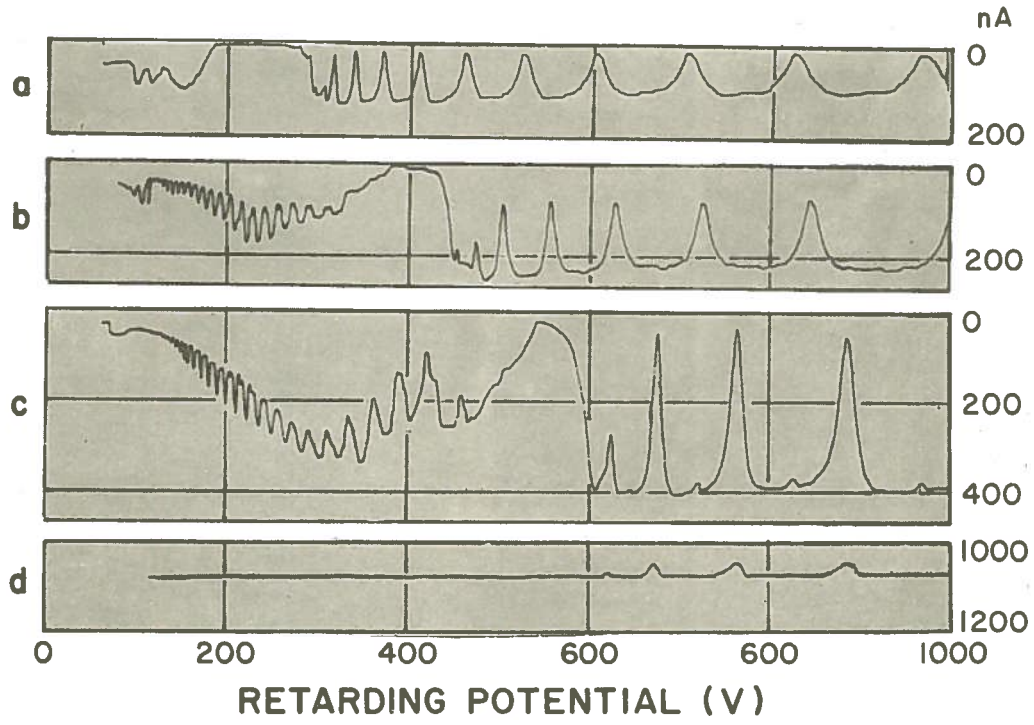
Dip No.	Energy E_j			$j+\left(\frac{1}{4}-\frac{\varphi}{2\pi}\right)$		
	Plot a	Plot b	Plot c	Plot a	Plot b	Plot c
1	317	477	623	21+0.066	20 –0.061	19 – 0.339
2	340	507	675	20+0.332	19 +0.338	18 – 0.067
3	370	558	763	19+0.489	18 +0.423	17 – 0.135
4	410	630	885	18+0.515	17 +0.344	16 – 0.339
5	460	727		17+0.480	16 +0.148	
6	523	847		16+0.388	15 –0.041	
7	603			15+0.264		
8	707			14+0.104		
9	823			13+0.065		
10	967			12+0.059		

Gun-grid distance =19cms, B = 177 Gs
Plot a: Beam Energy = 300eV, α = 0.78
Plot B: Beam Energy = 450eV, α = 0.92
Plot C: Beam Energy = 600eV, α = 0.97

potential is less (in magnitude) than the cathode potential.

We report now an even more astonishing observation as described below:

The grid potential is raised to a level [| Φ_{max} | ~ 1 kev] much higher than the cathode voltage Φ_c , (in magnitude) which is kept at values 600, 450, and 300V for three different runs (which leads to beam energies of 600, 450, 300 eV). The grid potential is then dropped from the value $-\Phi_{max}$ to zero, while we record both the plate current and the anode current. So long as the grid potential exceeds in magnitude the cathode potential Φ_c , the plate shows a zero current, which is not surprising. Likewise one would expect that the anode current would show a simple monotonic behaviour as the electrons pass across it, out of the gun and back into it, after being reflected by the grid, as long as the grid potential is higher than the corresponding beam energy. What we find in our experiments is again totally different from what one would expect from the standard classical mechanical understanding of the problem. We find well defined sharp dips in the anode current at specific values of the grid potential even when it is higher than Φ_c , indicating that the electrons respond to the monotonic variations in the grid potential in a non-monotonic manner even when the electrons are not able to reach the grid on which the potential is applied. This is reminiscent



1.13 a,b and c: Anode current profiles for beam energy = 300, 450 and 600 eV respectively, d is the cathode current profile corresponding to beam energy = 600 eV (gun-grid distance = 19 cms, B = 177 Gs).

of the Aharanov-Bohm effect in quantum mechanics. In these experiments since the plate and grid currents remain zero, the presence of dips in the anode current is again enigmatic. We have therefore measured the cathode current flowing to the ground as a function of the swept grid potential and have observed the presence of dips in the cathode current also at the same energy positions as those in the anode current. This indicates that the forbidden states are indeed characterised by a decrease in the extraction of electrons into the system. The experiments carried out for various gun to plate distances but maintaining the magnetic field and beam energy fixed and varying the beam energy, keeping the same magnetic field and gun-plate distance show that the positions of the observed dips in the anode current fit well with the relation

$$E_j = \frac{1}{2}\left(\alpha \frac{3\Omega L}{2\pi}\right)^2 / \left(j + \frac{1}{4} - \frac{\varphi}{2\pi}\right)^2$$

The factor α is found to be less than unity, so that (αL) would appear to represent the effective distance penetrated by the electron beam into the system when the retarding potential is actually higher than the beam energy. The beam under these conditions is thus not able to travel right up to the grid-plate assembly.

(R.K.Varma and A.M.Punithavelu)

List of Papers Published During 1992 - 93

1. R.K.Varma and A.M.Punithavelu, "Behaviour of Charged Particle Motion along a Magnetic Field and a Retarding Potential - Evidence for the Existence of Discrete Energy States in Classical Mechanical Domain",Modern Physics Letters A, **8**, 167 (1993).

Planetary Atmospheres And Aeronomy

The major research activities of the Planetary Atmospheres and Aeronomy Division are aimed to understand the various physical and chemical processes in the atmosphere. The studies include balloon and rocket borne in-situ measurements of various atmospheric constituents and parameters, ground - based radio and optical remote probing of the atmosphere, laboratory experiments for measuring photoabsorption and fluorescence cross section and modelling. The activities can be broadly classified into the following three categories.

(i) Middle Atmosphere - Chemistry, aerosols and radiation balance, ionization and dynamics.

(ii) Upper Atmosphere - Ionospheric phenomena, plasma density irregularities associated with equatorial spread-F and sporadic E, ionosphere-thermosphere coupling.

(iii) Laboratory Astrophysics - Photoabsorption and fluorescence spectroscopy, electron scattering cross section measurements, radiative life time measurements.

Global warming due to enhanced green house effect is of great concern in recent times. Methane plays an important role in green house effect and in the tropospheric- stratospheric chemistry. Methane flux measurements from Paddy fields reveal the flux to be strongly dependent on the growth of the paddy crop, maximising for a crop of 50-80 days age while other factors like water level, stagnation period, soil temperatures etc. do have a significant control on the flux.

Water vapour is one of the prominent green house gases. The absorption cross section of this minor constituent in the red region 6575-6675A has been estimated from the absorption measurements in this wavelength region and at 4428A for which water vapour absorption cross section is accurately known from laboratory measurements. The absorption crossection is found to vary from 2×10^{-26} to 4×10^{-24} cm^2.

Balloon borne measurements and lidar sounding of the aerosol layers of Mt. Pinatubo origin reveal the layer to remain unperturbed upto one year since the volcanic eruption. During the following six months its concentration got reduced by a factor of two. The long life time of these aerosols indicate their potential to induce perturbation in the climate.

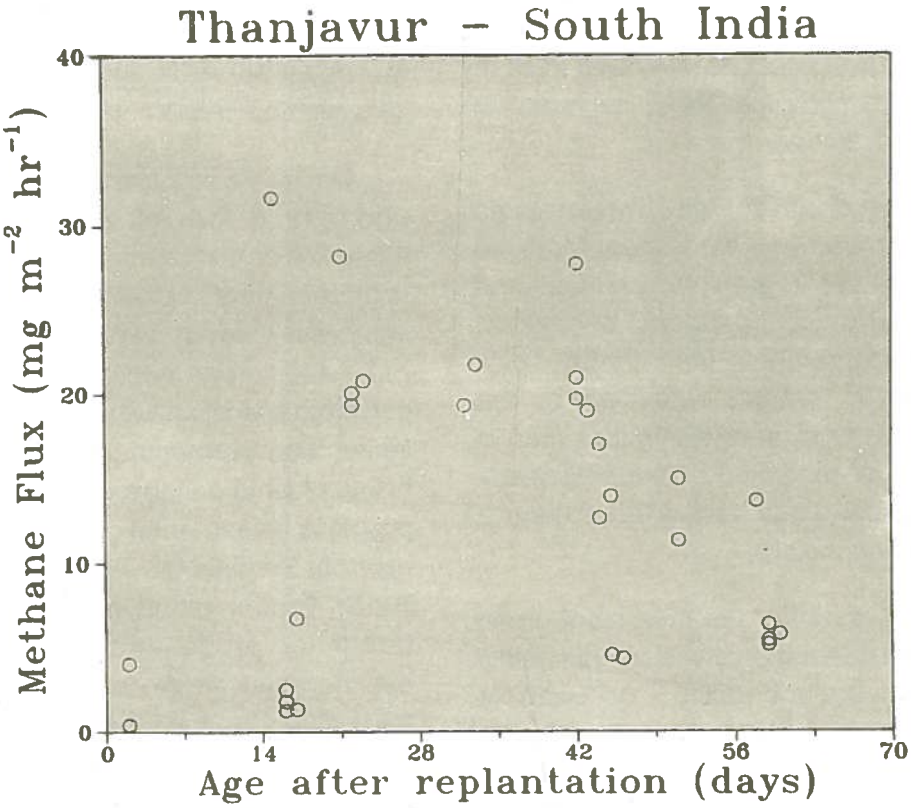
The possibility of middle atmospheric ion conductivity measurements being contaminated by photoelectric effect at the sensor end is getting sorted out. The difference in positive and negative ion conductivity is explained due to photoelectric effect at altitudes above 30 km. A seasonal dependence on the threshold height where this effect becomes significant has also been brought out for the first time.

The Dayglow photometer has been used to study the evolution of Equatorial Ionization Anomaly (EIA) thus providing the first ground based optical investigation of EIA and related phenomena.

One of the ambitious programmes has been to understand the role of neutral atmospheric dynamics on the initiation of equatorial spread-F. A comprehensive rocket experimental programme alongwith a set of complementary ground based radio and optical experiments was planned and executed successfully (see title page).Coordinated insitu measurements of neutral winds, electric fields, plasma densities and neutral and ion compositions were carried out using two RH-560 rockets from Sriharikota. Two rockets, one containing Ba-Sr vapour cloud and the other containing Langmuir probe and neutral and ion mass spectrometer, were launched on February19, 1993, one after the other within 30 minutes at the onset time of ESF. The occurrence of ESF was predicted using the data obtained from dayglow photometer from Waltair and ionosonde at SHAR. All Sky Imaging Spectrometer, Dayglow Photometer, All Sky Imaging Camera, HF Doppler

radar, Ionosonde, MST Radar, VHF and UHF satellite scintillation receivers were operated for complementary ground based measurements. Both the flights were successful and all the groundbased equipments worked satisfactorily. The data, unique in many ways, are being subjected to detailed analysis and is expected to provide answers to some of the unresolved questions like the day to day variability exhibited by the equatorial spread-F.

The research activities undertaken by the Laboratory Astrophysics group include setting up of a laser laboratory to carry out some sophisticated experiments in atomic and molecular physics. An excimer-laser pumped tunable dye-laser has recently been installed to achieve such goals. The experiments to be carried out include the study of fluorescence spectra of weak fluorescing systems, measurement of radiative life times of molecules and the study of multiphoton ionization of molecules through resonance enhanced multiphoton ionization process. An experimental chamber which would house all the three experiments has been designed and is being fabricated in our machine shop. The system is expected to be operational in near future and some research activity in this direction would start during the next year. Two new experiments became operational during the year. In the first experiment, the



2.1 Variation of methane flux with the age (after replantation) of the rice plants

photoabsorption cross sections are being measured for sulphur dioxide from 200 to 400 K at incident photon wavelengths from 170-330 nm whereas work on fluorescence spectroscopy of CS_2 at different temperatures has just been taken up. The electron scattering cross section measurements for nitric oxide at low electron energies have also been started using a photoelectron source. Some of these measurements like photoabsorption cross sections are required to model ground based and satellite UV albedo observations of planetary atmospheres whereas the electron scattering cross sections measured in the laboratory could be used to model certain properties of the planetary ionospheres.

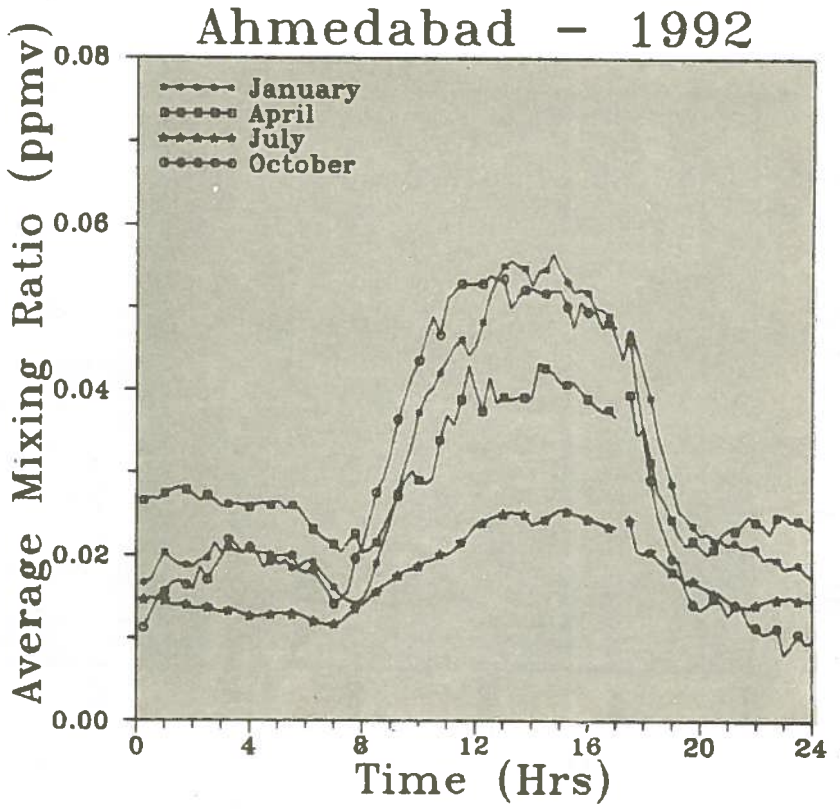
MIDDLE ATMOSPHERE

Minor Constituents

Variations of Methane Flux during a Full Growing Cycle

During the last two years, measurements of methane flux have been made from paddy fields in the Thanjavur region. Air samples have been collected at different phases of the growing period of the crop. These samples have been analyzed for methane concentrations and fluxes have been estimated.

Fig. 2.1 shows methane flux values at different stages of the crop (age of plant) from September



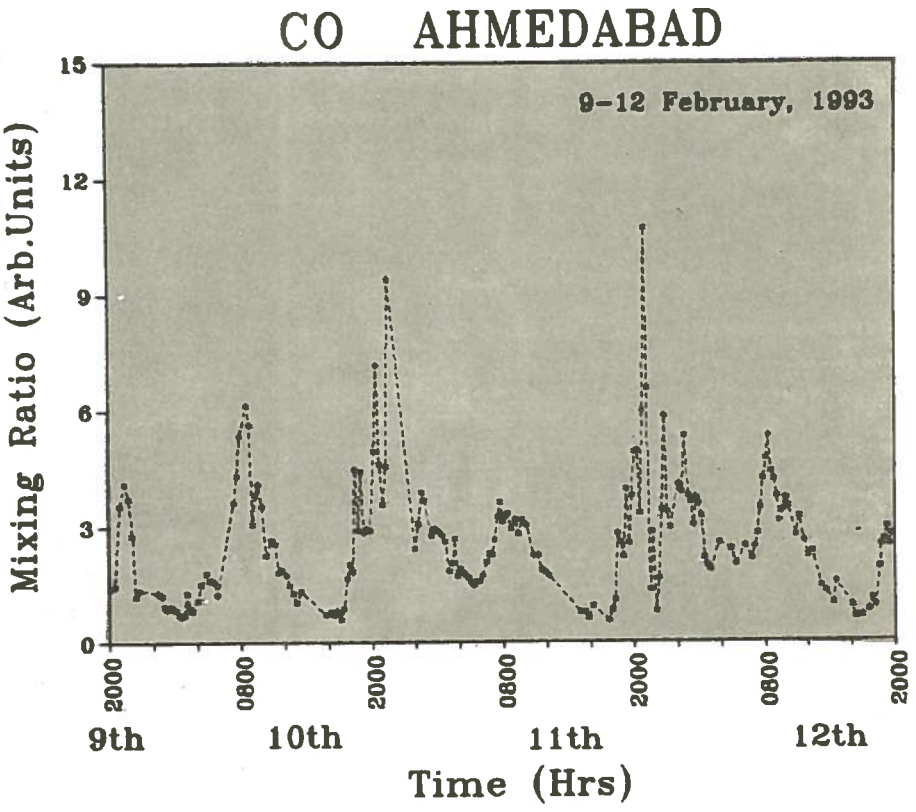
2.2 Monthly average diurnal variation of surface ozone measured at Ahmedabad

to January 1991-92 and 1992-93 periods. Generally the crop period is about 120 days. The replantation is done after about 30 days and the measurements are done in the replanted fields only. The flux value increases from a low value in the range of 1-4 mg/m^2/hr for young plants of 30-45 days and reaches maximum at the plant's age of 50-80 days. Most of these flux values fall in the range of 15 to 25 mg/m^2/hr. After about 80-90 days of age, the methane flux decreases. This shows that a single value can not be used for estimating total flux from the paddy fields for the entire season. The spread in the flux values is also due to various other factors, such as water level, stagnation period of water in the field, soil temperature, etc. In addition, observations were also made in flooded soil and dry soil both without paddy. Very low flux values were observed in flooded soil while dry soil showed even a negative flux representing it as the sink for methane.

(S, Venkataramani, Shyam Lal, B.H. Subbaraya and T.K. Sunil)

Tropospheric Chemistry

Surface ozone at Ahmedabad : Tropospheric ozone plays an important role in the chemistry of this region as well as in the greenhouse warming. Recent measurements have shown that there is an increase in the amount of tropospheric ozone and this is attributed to local production by NO_x, CO, CH_4 and non-methane hydrocarbons (NMHCs). As a part of the I/D-GBP a programme has been initiated recently to monitor ozone and its precursors at a few selected stations representing



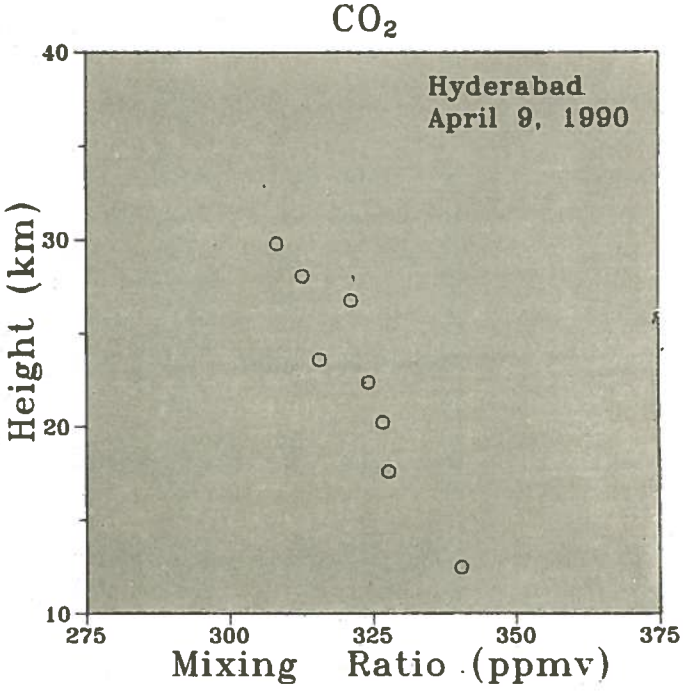
2.3 Variability in the concentration of carbon monoxide (CO) measured at PRL, Ahmedabad for a period of three days in February 1993

different eco-systems. Ozone monitoring started at Ahmedabad since November 1991.

Fig. 2 .2 shows monthly average diurnal variation in surface ozone at Ahmedabad for few selected months representing different seasons. In the winter season (January) the ozone concentration as well as the diurnal amplitude are higher compared to that in summer months. While the diurnal maximum occurs around noon time in all the seasons when the solar flux is high indicating strong control of in-situ photochemical production, the similar direct correlation is not seen on a seasonal basis. The cause for this is being investigated.

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

Simultaneous measurements of surface ozone and its precursors: Tropospheric ozone can be produced photochemically if its precursors like NO_x, CO, CH_4, NMHCs are present in abundant concentrations. Simultaneous monitoring of these gases would enable to model changes in ozone concentrations. We have conducted simultaneous measurements of O_3, CO and CH_4 continuously for 3 days during February 1993 at Ahmedabad as a test run. While the ozone is monitored using the automatic monitoring system, CO and CH_4 are measured using gas chromatographic technique operated manually roughly at every 20 minutes interval.

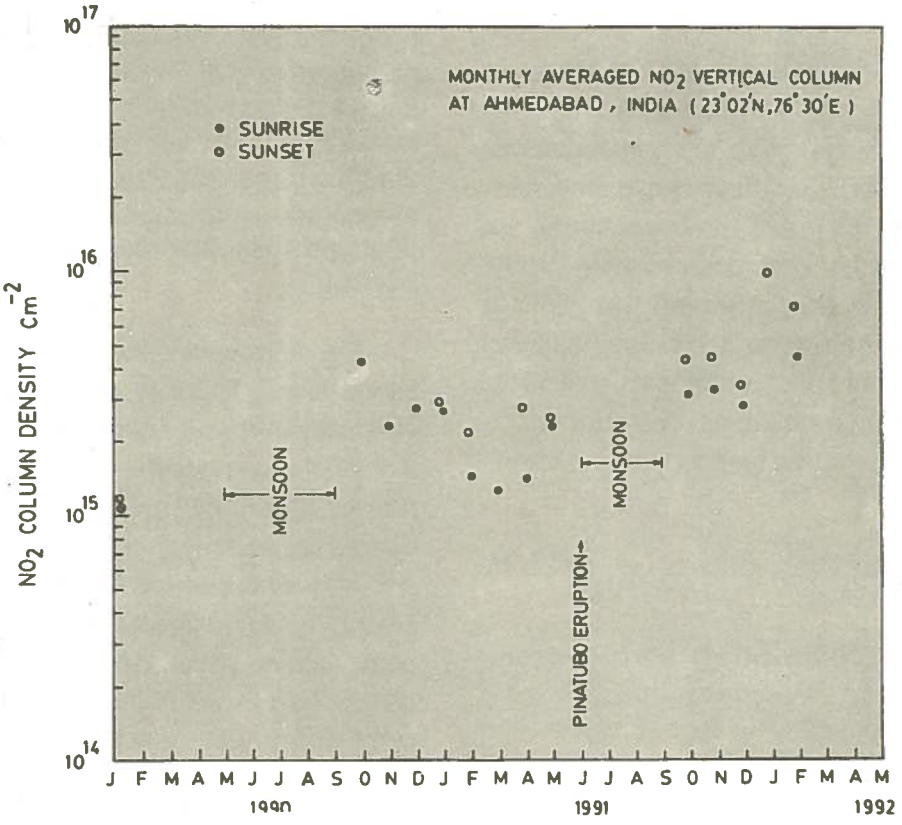


2.4 Vertical distribution profile of carbon dioxide obtained from the samples collected cryogenically during the balloon flight conducted from Hyderabad on April 9, 1990

Fig. 2.3 shows observed variations in CO concentration. There is a large systematic diurnal variability in the CO concentration seen on all the 3 days of observations. CO is high during morning hours, peaking around 8 A.M. thereafter it decreases and reaches a minimum around 4 P.M. and after about 6 P.M. it starts building up again. During night time, there are large changes and the peak values, which occur around mid-night, are higher than the morning 8 A.M. peak values. Almost similar variability has been observed in CH_4 values, except the absence of the morning 8 A.M. peak. This is the first set of measurements. More measurements are planned so as to understand these variabilities and the related chemical and dynamical processes.

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

Vertical distribution of carbon dioxide : Carbon dioxide is the major greenhouse gas, but it is a chemically inert gas. Its distribution in the atmosphere is governed mainly by dynamics. Hence its vertical distribution can be used to infer the exchange rate between troposphere and stratosphere. Air samples were collected by cryogenic sampling at different heights between 10 and 35 km during the balloon flight conducted from Hyderabad on April 9, 1990. Some of these samples have been analyzed at PRL using an infrared analyzer. The profile is shown in Fig. 2.4 CO_2 concentration decreases from a value of 340.5 ± 10 ppmv around 12.5 km to a value of about 308.3 ± 10 pmv in the height region of 29.8 km. The slow decrease with height is mainly



2.5 Long term variation of vertical columnar density of NO_2 over Ahmedabad obtained by visible absorption spectroscopy

due to transportation from the troposphere where it is steadily increasing.

(Shyam Lal and B.H. Subbaraya)

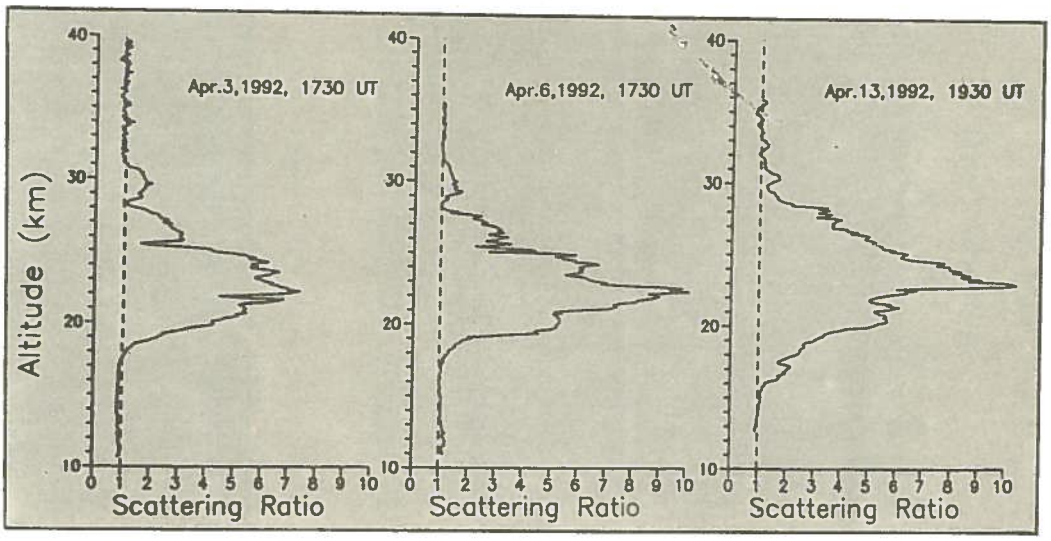
NO_2 Column Density after Pinatubo

Stratospheric column density of NO_2 is being measured at PRL since September 1989. Some results have been reported earlier. In June 1991, Mt.Pinatubo of Phillipines (14°N, 122°E) erupted. Johnson et al at the National Institute of Water and Air Research, Lauder, N.Zealand have reported a decrease in the slant column abundance of NO_2 by around 30 percent after Pinatubo eruption at Lauder (45°S, 170°E), New Zealand. Both Johnston et al and Perliski and Solomon at National Oceanic and Atmospheric Administration, Boulder, USA suggest that this decrease is due to heteorogenous chemistry - by conversion of reactive nitrogen to nitric acid. At Ahmedabad, however, we do not find any change in the slant column abundance of NO_2 after Pinatubo eruption. But the vertical column abundance has been found to increase by a factor of about 2 after Pinatubo eruption (Fig. 2.5).

(M. Lal, J.S. Sidhu, S.R. Das, K.V. Pandya and D.K. Chakrabarty)

Water Vapour Absorption Cross-section in the Red Region

Water vapour has significant contribution to the atmospheric absorption of solar radiation in the red region. But its absorption cross-section in this region is not properly known. To determine the



2.6 Scattering ratio profile obtained using Nd;YAG Laser Lidar over Ahmedabad. The dotted line shows the theoretically expected value for a Rayleigh atmosphere, in the absence of aerosol.

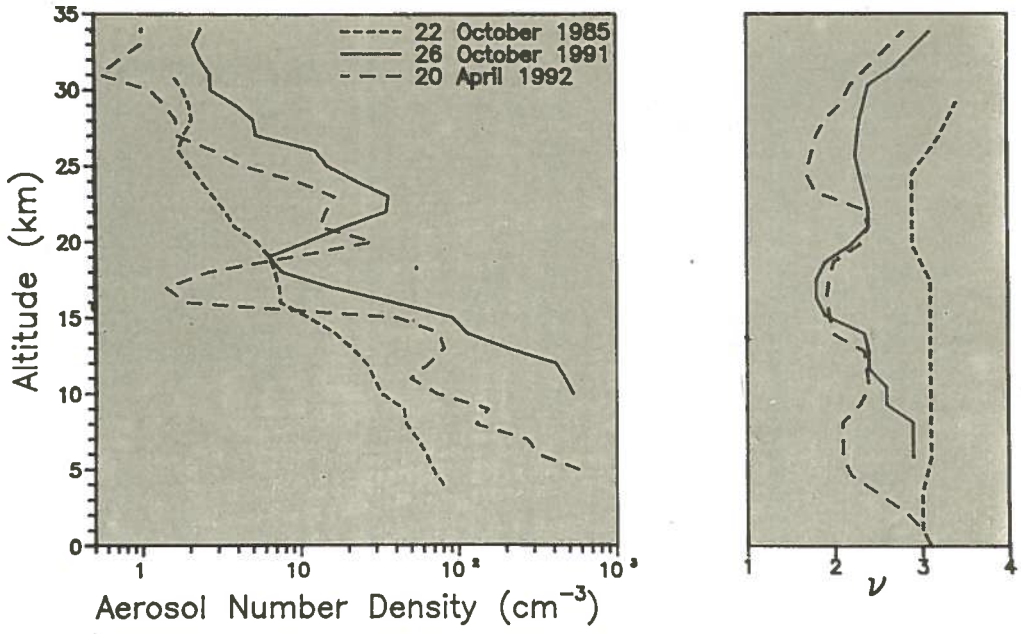
distribution of gases having absorption in this spectral region, it is necessary to know the value of water vapour absorption cross section in this region. We have derived the value of water vapour absorption cross section in the region 6575 to 6675 A by measuring the atmospheric absorption. Water vapour absorption cross section near 4428 A is accurately known from laboratory measurements. Absorption measurement near this wavelength gives the value of water vapour density. Further, absorption measurement has been made in the red region. Combining the absorption value with the water vapour density derived from the absorption measurement at 4428 A, the water vapour absorption cross section in this red region has been derived. The values vary from 2×10^{-26} to 4×10^{-24} cm^2 in the region 6575 to 6675 A at 5A instrument resolution. These values are to be verified by direct laboratory measurements.

(D.K. Chakrabarty, M. Lal and J.S. Sidhu)

Nd:YAG Lidar studies of Mt. Pinatubo Volcanic Aerosol in the Stratosphere

The Nd:YAG laser based Lidar system commissioned at PRL has continuously been used to probe the stratosphere since April 1992. With the present configuration of 400 mJ energy per laser pulse at 532 nm and a photon counting system coupled to a 40 cm diameter telescope, backscattered signal strength could be detected upto an altitude of about 40 km. One of the important and interesting results being obtained from the lidar studies is that of the volcanic aerosol layer existing between 18 to 30 km formed after the eruption of Mt.Pinatubo volcano in June 1991.

Fig. 2.6 shows typical profiles of the scattering ratio obtained with an altitude resolution of 96 metres. Continuous monitoring of the layer indicates that the layer remains unperturbed until about July 1992, an year after the eruption, and started decaying then. By December 1992 the total



2.7Comparison of aerosol concentration and size distribution profiles obtained before and after the Mt. Pinatubo volcanic eruption

amount of particles in the layer has reduced to half of its initial value. During major volcanic eruptions such as Mt. Pinatubo, large amount of sulphur dioxide is injected at the stratospheric levels. In about a month's time the volcanic plume not only circumnavigate the globe but also are converted into sulphuric acid droplets due to various chemical and physical processes going on at the stratosphere. These aerosol particles produced insitu at these altitudes are expected to remain aloft for about 3 to 4 years and can induce long term perturbation in climate. In order to study and model the various physical processes going on within the aerosol layer the system is now being augmented with a frequency tripling set up to get laser output at an additional wavelength of 355 nm. The dual wavelength monitoring of the layer will give additional information on the altitude distribution of the aerosol size parameter.

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

Studies on Mt. Pinatubo Volcanic Aerosol Layer using Balloon Borne Photometers

Two balloon flights were conducted from the National Balloon Facility at Hyderabad on 26 October 1991 and on 20 April 1992 respectively to study the aerosol layers at the stratospheric altitudes produced due to the Mt. Pinatubo volcanic eruption in June 1991.

The balloon experiments consist of automatic sun-tracking multichannel photometer assemblies to track the sun in elevation and to scan the sky in the azimuthal direction to obtain the direct solar radiation intensities as well as the angular distribution of the scattered radiation intensities at ten different wavelength regions from UV to IR.

Figure 2.7 shows the altitude variation of aerosol number density and the aerosol size distribution parameter obtained from the balloon experiments. During October 1991, the number density profile indicates a dense layer of aerosols between 19 and 27 km. The peak of the aerosol

layer is seen at 23 km. The size distribution parameter in the altitude range 17-21 km is about 1.8, indicating a relatively larger fraction of bigger particles in this region, formed due to gas(sulphur dioxide) to particle conversion. During April 1992, the aerosol layer extends between 17 and 27 km and the peak lies at 20 km, indicating that the aerosol layer has started settling down, about an year after the eruption. The size distribution profile in 1992, indicates 2 layers, but the lower layer below the tropopause could be due to local effects. The aerosol number densities also show a decrease from 1991 to 1992. But, both the results indicate that the aerosol number densities are about one order of magnitude higher, when compared with the 1985 results, which was a volcanically quiescent period representing the background aerosol conditions. This indicates the magnitude of the volcanic eruption, which is believed to be the strongest in this century.

Attempts are being made to develop a one dimensional model to explain the stratospheric aerosol layer formation after a major volcanic eruption like Mt. Pinatubo and the decay features. The impact of the aerosol layer on the radiative transfer is also being studied.

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

Determination of Aerosol Characteristics using Particle Sampler and Sun Photometer

Aerosol characteristics (namely total aerosol loading into unit volume, refractive index and size distribution) are necessary to introduce aerosols into radiative transfer calculations. To do this as realistically as possible, systematic measurements have to be carried out using both remote sensing methods as well as direct sampling.

Measurements of aerosol size distribution were made using a 14 stage particle sampler (Andersen Impactor). Sampling is done by directly sucking in air through layered sieves, and particles belonging to different size ranges between .80 and 35 micron are deposited on the collecting substracts kept below each stage. Utmost care has been taken to avoid possible contamination by moisture. Particles collected on the substractes are weighed with an accuracy of .01 mg using Sartorius electronic balance. The mass distribution is then converted into size distribution by assuming a weighted average of the components of an urban aerosol model.

The aerosol over Ahmedabad shows a bimodal, and sometimes a trimodal distribution, peaking at radii 18.7, 8.55 and 1.7 micron. Though normally, only two principal modes show up even in a trimodal distribution, a heavy loading of industrial soot over Ahmedabad may explain the present observations. Simultaneous measurements of aerosol optical depth by sun photometer show that the optical depth versus wave length graph peaks at or around the same radii correspoding to the maxima in the size distribution curve.

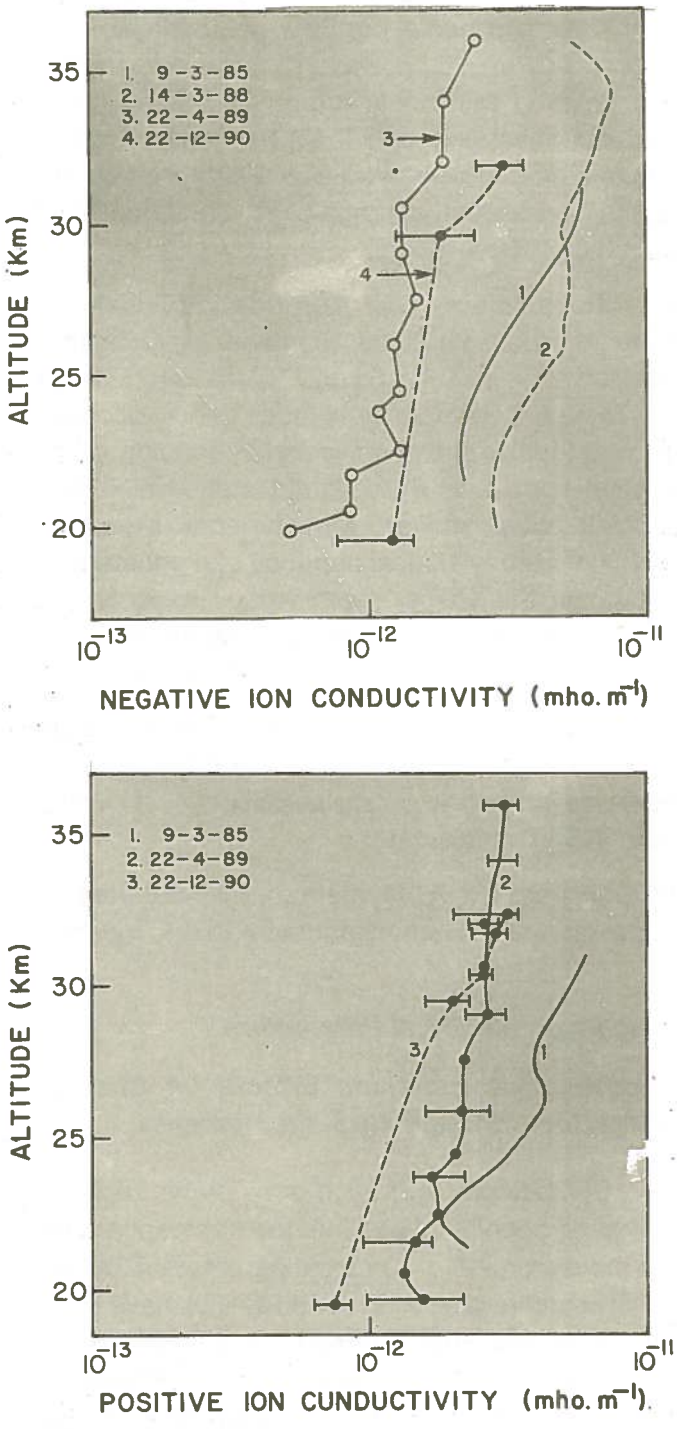
These results form part of the ground truth data aimed at validating the retrieval algorithm currently being developed to obtain aerosol optical depths from INSAT visible data.

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

Studies on Electrical Parameters

Photoelectric Emission Effects on Stratospheric Ion Conductivity Measurements

Photoelectric emission from probe surfaces that have been launched into the stratosphere for the measurement of electrical parameters like the positive and negative ion conductivities have been shown to possibly contaminate the measurements. The threshold altitude beyond which photoelectric effect becomes significant is determined by the workfunction of the probe surface for a given solar condition. Aquadag coated relaxation probes (workfunction 4.6 eV) when used in balloon flights with controlled float altitudes reveal the threshold



2.8 Profiles of negative and positive ion conductivities obtained by Balloon-borne spherical probe over Hyderabad during IMAP period

heights to be 30 km for equinoctial months and 32 km for winter months showing a strong seasonal dependence. These measurements have been confirmed by means of independent spherical D.C. probes also (Fig. 2.8). Further large spatial variability in the conductivities have also been detected presumably due to atmospheric chemistry.

(D.K. Chakrabarty, S.P. Gupta, S.R. Das and K.V. Pandya)

Tropospheric Studies using MST Radar

Spatial fluctuations in the radio refractive index in the atmosphere give rise to the scattering or Fresnel reflections of radio waves. It is possible to derive some properties of these spatial fluctuations, also known as irregularities/structures, from the radar echoes. For example the signal statistics like the amplitude probability distributions characterise the nature of scatterers. In case of a large number of isotropic scatterers the resultant fading will be deep with Rayleigh type of amplitude distribution. In case there are high anisotropic irregularities or structures the signal would be stronger and describe a normal amplitude distribution. Thus the Rice parameter, which is a measure of the relative contributions of the specular type to random type of signals, can be determined from the signal amplitude. In addition the anisotropic irregularities would cause strong aspect sensitive nature of echoes (strong angular dependence). An experiment was conducted using national MST radar facility at Tirupati on 8 February 1992 for studying the nature of irregularities/structures in troposphere. 16 μs pulse with coding was used to achieve 1 μs resolution (150 m). Raw data were collected for about an hour and half. Theoretical amplitude distributions have been computed for different values of the Rice parameter. Experimentally observed distributions have been obtained for some of the scans and are compared with the theoretical curves for best fit using Chi square test. The altitude profiles of the Rice parameter is thus obtained. These results along with the aspect sen-

sitivity studies from echo measurements at every two degree steps of beam direction, made on a day by SAMEER group will yield important information on the nature of irregularities at different altitudes.

(H. Chandra, N.S. Shah and H.S.S. Sinha)

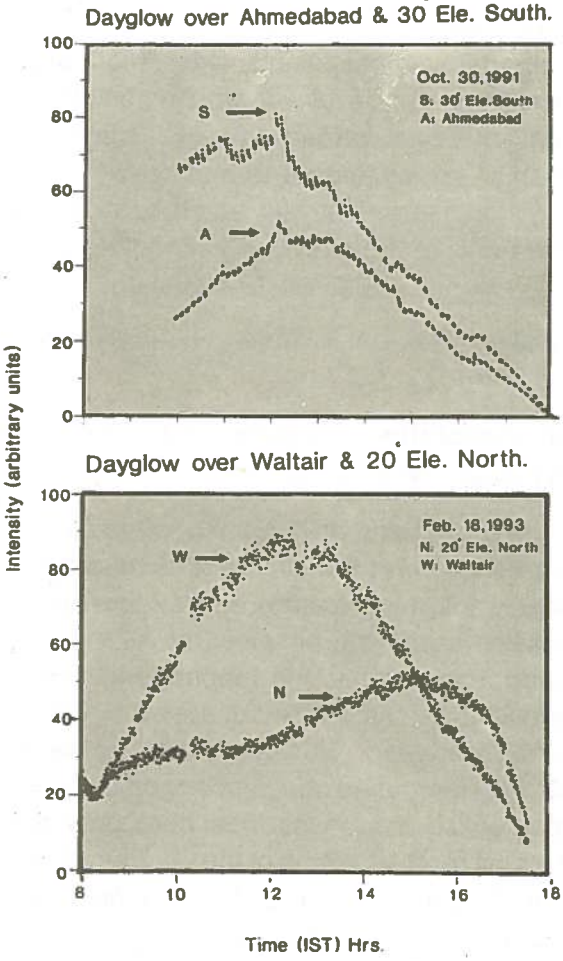
UPPER ATMOSPHERE

Studies on the Development of Equatorial Ionization Anomaly and its Application

Earlier observations made using the dayglow photometer on OI 630.0 nm line emission from thermosphere and theoretical investigations on the causative mechanism revealed the following results.

1. The observation from an equatorial station SHAR showed the development of noontime bite-outs in the emission intensities on certain days and also revealed good correlation between the temporal variation in the emission intensities and the maximum electron densities at the F region during high sunspot years.
2. The observation from a low latitude station Mt. Abu showed the development of noontime bite outs in the emission intensities on several occasions. The temporal variabilities in the intensities show a good correlation with the electron densities in the altitude region of 200-300 km over Ahmedabad with a time delay of 1 hour. This time delay is interpreted as the time taken for the movement of Equatorial Ionization Anomaly(EIA) crest from Ahmedabad to Mt. Abu which is separated by 2^{o} in latitude.
3. Theoretical estimation of the intensities using the electron density data from Ahmedabad reveals that the temporal variations in the dayglow intensities are solely due to the temporal variations in the electron densities in the altitude range of 200-300 km and the electron density in this altitude region contributes upto 35% of the total dayglow intensities.

These results indicate that the measurement of dayglow intensities from a single station at two different elevation angles corresponding to two different latitude locations can effectively be used to study the movement of EIA crest. Moreover, earlier studies using ionosonde reveal that the occurrence of equatrorial spread F is related to the development of EIA. With these points in view, a coordinated campaign was planned and conducted by operating the dayglow photometer in a sky scanning mode from Waltair (a station in between



2.9 Temporal variations of 630.0 nm dayglow intensities at two different elevation angles taken from Ahmedabad and Waltair depicting the evolution of Equatorial Ionization

SHAR and Ahmedabad) and ionosondes from Waltair, Ahmedabad, Trivandrum and SHAR (Fig. 2.9). The important results obtained from this campaign are:

1. The zenith dayglow intensities (I_W) (corresponding to 10.6°N dip latitude) are more upto 1500 IST compared to the intensities(I_A) obtained at low elevation angle (corresponding to 16.8°N dip latitude) inspite of more columnar advantage for the latter case. This indicates that the EIA crest moves north of Waltair region only after 1500 IST during the month of January and February 1993 confirming the earlier results on EIA evolution based on a chain of ionospheric sounders.
2. The ratio of intensities (I_A/I_W) are found to increase more steeply after 1600 IST and reaching a value of ~ 2 around 1640 IST itself on equatorial spread - F (ESF) days much earlier as compared to nonspread - F days. This measurement has an advantage of inferring one of the necessary conditions for the occurrence of ESF well in advance.

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

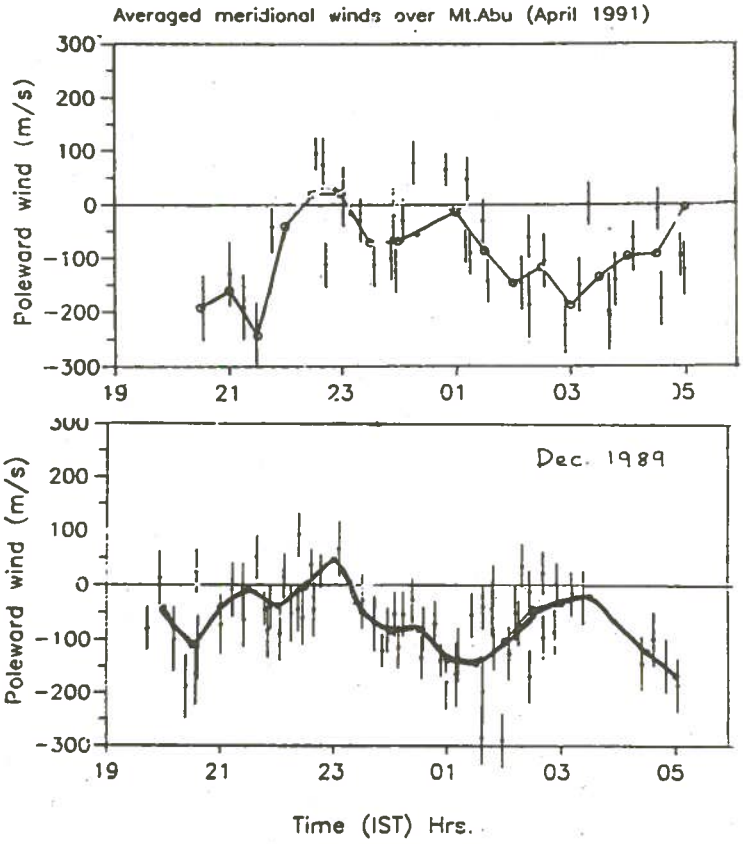
High Resolution Imaging of the Equatorial Thermosphere Airglow Emission

The design and development of an all sky imaging Fabry-Perot Spectrometer to map thermospheric winds, temperature and airglow emission intensities under the auspices of All India Coordinated Programme for Ionospheric-Thermospheric Studies (AICPITS) supported by DST was reported last year. This instrument, comissioned at Mt. Abu for routine observations on OI 630.0 nm airglow emission from thermosphere, provided the first visual representation of the reverse equatorial plasma foutain due to equatorward movement of the Equatorial Ionization Anomaly (EIA) crest during nighttime. The above spectrometer was operated from an equatorial station (Kalpakkam) during the month of February 1993 to understand the equatorial thermosphere-ionosphere system during the ESF rocket campaign period, alongwith other supporting groundbased equipments. The preliminary result obtained from this campaign shows that the development of Fabry-Perot fringes start from lower elevation angles to zenith with time (see back cover). This is due to the increase in the plasma content in the horizontally stratified emitting region due to the downward movements of F- region plasma during nighttime. These data are being analysed to bring out large scale spatial structures in the airglow emitting region.

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

Low Latitude Thermosphere - Ionosphere System

Thermospheric line of sight winds and temperatures are obtained regularly from Mt. Abu using a central aperture pressure scanning Fabry-



2.10 The nocturnal variations of the averaged meridional wind patterns during April and December months

Perot Spectrometer during night time. The average meridional wind pattern during the months of April (1991) and December (1989) shows an interesting feature (Fig. 2.10). Most of the time the wind is equatorward for both April and December months. The maximum equatorward wind after midnight is seen at 0130 IST during December while the same is seen at 0300 IST during April month. The emission intensity maxima are also observed to be nearly at the same time during these months. Since the OI 630.0 nm intensity is directly related to the F-region plasma densities in the nighttime, enhanced intensities are known to be linked to the presence of the crest of EIA. Therefore it is inferred that the maximum equatorward wind is colocated with the EIA crest thus providing the first groundbased evidence for the recently discovered phenomenon known as Equatorial Temperature and Wind Anomaly(ETWA) based on satellite data.

(S. Gurubaran, R. Narayanan, R. Sekar, N.K.Modi, D. Pallam Raju, Ranna Patel, Manisha Pandya and R. Sridharan)

VHF Scintillations at Low Latitudes

As part of the All India Co-ordinated Programme of Ionosphere and Thermosphere Studies (AICPITS), regular VHF scintillation measurements at 244 MHz are being made at about twenty stations in India covering a latitude region from magnetic equator to 40° diplat. Data during March-April 1991 at all stations have been jointly analysed along with the ionosonde data at Thumba, SHAR, Waltair and Ahmedabad. These measurements, from a large network, are the first of their kind, and have allowed one to study both the temporal and latitudinal variations of the scintillations at low latitudes in the Indian Zone. The onset of scintillations occurs around 1930-2000 hr IST for this epoch with a systematic time delay from equator to the increasing latitude. The scintillations at equatorial stations generally occur in a continuous patch of longer duration while in the anomaly peak region and beyond it breaks up in discrete patches of smaller duration. The maximum mean quarter hourly percentage occurrence of scintillations decreases from about 60 percent at the equator to 10 percent at Delhi. The half width of the equatorial belt of scintillations is around 15° in the premidnight and midnight periods but only 6° in the post midnight periods. This work is done jointly with the various university/institutions participating in the AICPITS scintillation network.

(H. Chandra and G.D. Vyas)

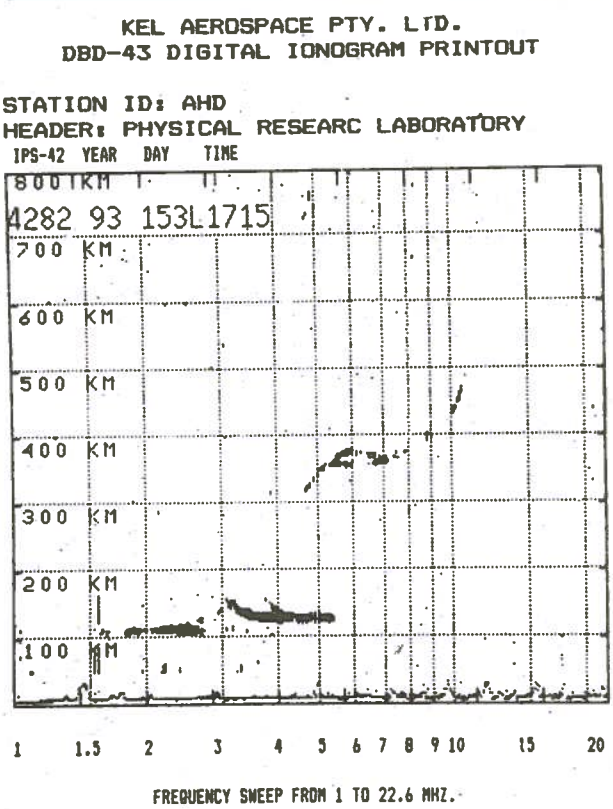
Ionosonde

Ionospheric soundings are regularly made over Ahmedabad for over four decades. The existing C_4 ionosonde dating back to pre IGY period, with film recording has been replaced by a modern KEL digital ionosonde since March 1993. The new ionosonde has on- line ionogram print out facility along with digital recording of data on magnetic cartridges. With the additional software it will be possible for a faster automatic scaling of the various ionospheric parameters. The ionosonde data has been used to study (i) the role of neutral winds and temperature in the F-layer height along with the Fabry-Perot spectrometer data from Mt. Abu. (ii) The F-region irregularities associated with the VHF scintillations recorded at Ahmedabad/Rajkot and Bombay and (iii) the effect of x-ray bursts from pulsar on the ionospheric absorption of HF waves (Fig. 2.11 and 2.12).

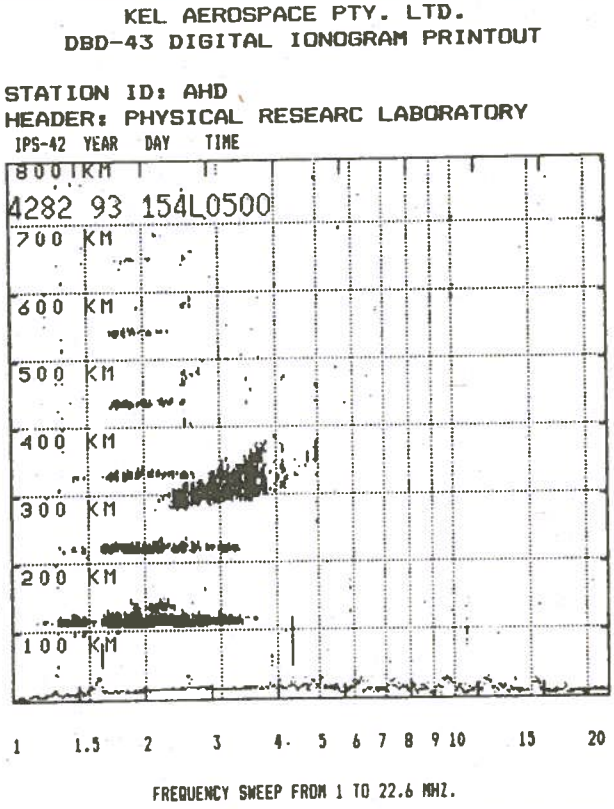
(G.D. Vyas, Bharati Bhatt, R.N. Misra, H. Chandra, N. Dutt and N.S. Shah)

Study of the Martian Magnetotail

The measurements shows that Mars is losing oxygen at the rate of 10^{24} or 10^{25} ions/s, through the magnetotail which is about two orders of magnitude less than that on earth. Two acceleration processes which could be possible mechanisms to explain the observed variabilities in oxygen ions in the magnetotail of Mars have been suggested. These mechanisms are (1) polar wind and (2)



2.11 Typical example of an evening ionogram over Ahmedabad from the newly installed KEL Digital Ionosonde



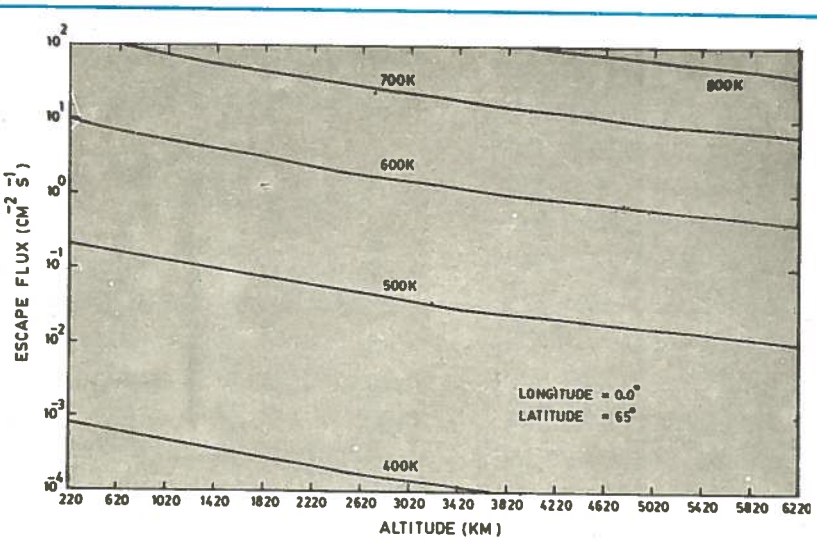
2.12 An example of the ionogram over Ahmedabad at 0500 hr showing strong blanketing type of sporadic E layer with several multiple reflections

plasma mantle. We have considered the first mechanism to explain the existing oxygen ions in the magnetotail for the first time. In this mechanism the ionospheric plasma can escape if their kinetic energy is high enough and would be accelerated due to electric field along the magnetic field lines through the polar region, where the magnetic field lines are open and connected with the magnetotail. Liouville's theorem is applied to obtain the velocity distribution of the thermal particles in the exosphere above the baropause.

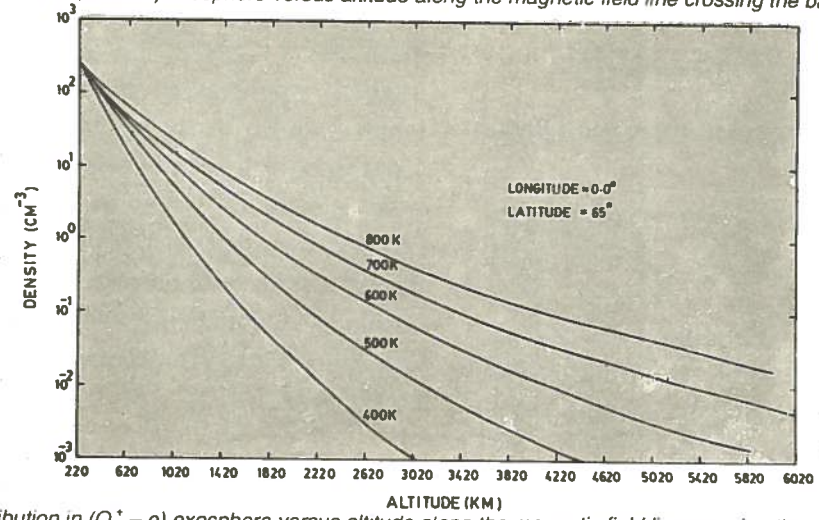
A three dimensional picture of the magnetic field line configuration within the magnetosphere of Mars using the spherical harmonic series is obtained, by assuming that solar wind incident perpendicularly upon the magnetic dipole which is colinear with the axis of planetary rotation. It has been found that the field lines are opening above 60 degree latitude and compressed on both day and night sides due to the solar wind effects.

The calculated magnetic field line intensity is used further in the calculation of escape flux, velocity and density of oxygen ions at different altitudes starting from 220 km at a latitude of 65 degree (Fig. 2.13 , 2.14, 2.15). The electric field in this region has been calculated by taking into account two fundamental conditions. (1) Quasi-neutrality has to be satisfied every where in the exosphere. (2) Escape fluxes of electrons and oxygen ions have to be equal. The other ions like CO_2^+ , CO^+ and O_2^+ existing in the ionosphere will not escape because of their heavy masses.

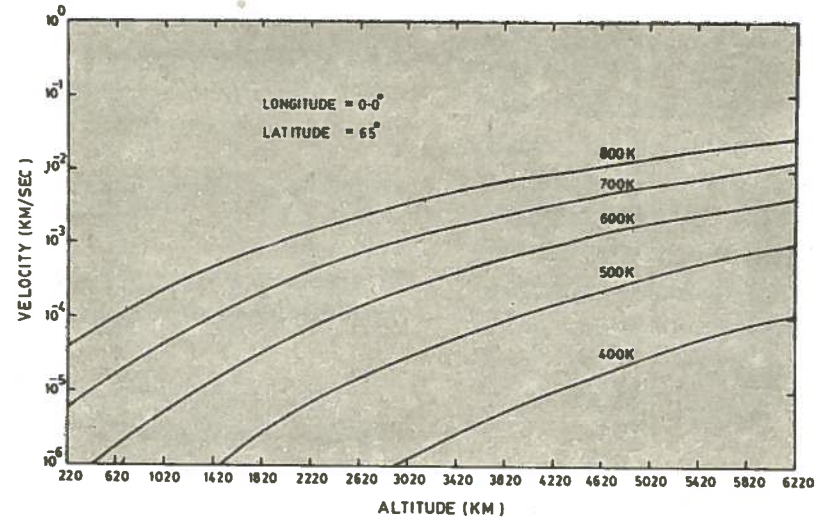
The calculations are carried out at different exospheric temperatures varying from 400 - 800 K. The total oxygen ions which are lost from martian exobase are $2\pi r_c^2 F \approx 1.2 \times 10^{20}$ ions s^{-1} where $F = 1.5 \times 10^2$ $cm^{-2}s^{-1}$ at Te = 700 K and r_c = 3610 Km (distance from martian centre to the exobase; radius of Mars is 3390 km). The calculation



2.13 Flux distribution in (O^+ – e) exosphere versus altitude along the magnetic field line crossing the baropause at 65 ° latitude



2.14 Density distribution in (O^+ – e) exosphere versus altitude along the magnetic field line crossing the baropause at 65 ° latitude



2.15 Mean velocity distribution in (O^+ – e) exosphere versus altitude along the magnetic field line crossing the baropause at 65 ° latitude

is also made at T_e = 1700 K where we get the escape flux $F \approx 1.2 \times 10^6$ $cm^{-2}s^{-1}$ and escape rate ~ 10^{24} $ions^{-1}$ comparable to the observation taken by TAUS and ASPERA experiments. Thus from the present study we arrived at two important conclusions. (1) If the polar wind is the only source of oxygen ions existing in the magnetotail of Mars, the nighttime exosphere temperature (T_e = 700 K) should be more by a factor of 2.5 or (2) The contribution of second source of plasma acceleration mentioned above should be taken into account.

(S.A. Haider and B.H. Subbaraya)

LABORATORY ASTROPHYSICS

Electron Scattering Cross Sections for Nitric Oxide

The measurement of absolute total electron scattering cross sections of atoms and molecules at low electron energies has, in general, been carried out in the past using electron beams produced by the combination of electron gun and appropriate electron optics. Recently, a new technique has been reported by our group wherein the electron impact cross sections are measured using a photoelectron source. Photoelectrons at different energies are produced by the interaction of EUV photons at different wavelengths and a source gas at low pressure. Using this technique, absolute electron scattering cross sections have been measured in the past in our laboratory for helium, neon, argon, krypton, xenon, molecular hydrogen and molecular oxygen at low electron energies from 0 to 10 eV. These measurements have been carried out with an accuracy of better than ±3%. Recently, work on the measurement of such cross sections have been taken up for nitric oxide. Work in this direction is in progress and would be completed in near future.

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

Photoabsorption Cross Section Measurement for Molecules at 200 - 400 K

A new experiment to measure photoabsorption cross sections for molecules at different temperatures ranging from 200 to 400 K and at incident photon wavelengths from 170 to 330 nm has been designed and fabricated in the laboratory. Most of the sub-assemblies of the experiment were fabricated last year as reported in the last annual report. During the current year, the experiment was made operational and the measurement to obtain photoabsorption cross sections for sulphur dioxide were undertaken.

The photoabsorption cross sections for a molecule at a certain incident photon wavelength may be appreciably different for different gas temperatures. At temperatures other than room temperature, the number of molecules in different initial vibrational states are varying and also, the transition prababilities from these initial states to the final state change drastically. Such measurements are required to model ground based and satellite UV albedo observations of planetary atmospheres.

Photoabsorption cross sections for sulphur dioxide have so far been measured in the photon wavelength region, 185 - 235 nm at only a few temperatures. All these measurements have been carried out at an instrumental photon beam width of 0.1 nm. These limitations are proposed to be overcome in the near future.

(V. Prahlad, S.M. Ahmed, Vijay Kumar, A.P. Gohil, I.T. Kriplani, J.K. Dave and V.K. Lodha)

Fluorescence Spectroscopy of Molecules at Different Temperatures

A new experiment has been designed and fabricated in the laboratory to study the fluorescence spectroscopy of molecules at different temperatures ranging from 200 to 400 K. The measurement is carried out at three incident

photon wavelengths of 58.4, 73.6-74.4 and 121.6 nm and relative production cross sections for different product states are obtained as a function of temperature. The fluorescence spectra is studied in the emission wavelength region from 200 to 700 nm depending upon the molecule under study.

During the year, the system was modified to take care of any change in incident photon intensity of the light source during the experiment. A beam splitter consisting of a wire mesh mounted at 45° to the incident photon beam and a combination of light guide coated with scintillator and a photomultiplier was fabricated and incorporated between the light source and the fluorescence chamber. This modification in the experimental set up has vastly improved the performance of the system. The experiment has become operational and some work has already been carried out for carbon disulphide and the relative production cross sections for B - X system of CS_2^+ have been obtained at a few temperatures. More work is needed to complete such studies for CS_2 . This would be carried out in near future.

(I.A. Prajapati, Vijay Kumar, A.P. Gohil, I.T. Kriplani and J.K. Dave)

Atomic and Molecular Physics with Lasers

A new laser laboratory is being set up to carry out certain type of basic and applied experiments in atomic and molecular physics. An excimer-laser pumped tunable dye-laser has very recently been installed in our laboratory to achieve such goals. The experiments to be carried out include the study of fluorescence spectra of weak fluorescing systems, measurement of radiative life times of molecules in different electronic states and the study of multiphoton ionization of molecules through resonantly enhanced multiphoton ionization process. It is proposed to carry out some of these experiments in the near future.

A new excimer-laser pumped tunable dye-laser has been installed in the laboratory having a useful spectral range from ultra- violet to near infra-red region. Lasing radiation of wavelengths corresponding to argon fluoride, krypton fluoride, xenon chloride and xenon fluoride could be obtained using the excimer laser. The maximum pulse energy measured at low repetition rate varies from 100 to 200 mJ for the above dimers whereas the repetition rate could be varied from 1 to 100 Hz. The nominal pulse duration is about 20 ns (FWHM) and beam shape is rectangular A tunable dye-laser is pumped with high efficiency by the excimer laser. The fundamental tuning range using different dyes covers a broad spectrum from 320 to 970 nm. The pulse width is similar to pump laser or slightly shorter and the output beam is nearly circular. Both excimer laser and dye laser have been procured from LAMBDA PHYSIK.

The three experiments proposed to be carried out in the laboratory can be conveniently housed in the same experimental chamber, even though one of these is remotely connected with the other two so far as physics is concerned. The first experiment involves the study of fluorescence spectra of weak fluorescing system like NO_2 at different temperatures whereas the second one deals with the measurement of radiative life times of the excited states of different molecules like CO, CO_2 etc. In both these experiments an expanded laser beam is required for interaction with effusive molecular beam. This would be done by using an appropriate beam expander in between the laser beam and the collision region. The third experiment relates to the study of multiphoton ionization of a molecular system. In this experiment, a very well focussed laser beam is allowed to interact with the molecules in the collision region. To start with, NO_2 molecular system would be taken up to study (n + 1) resonantly enhanced multiphoton ionization. Some new optically forbidden molecular states would be investigated through this process.

A combined experimental chamber to house all the experiments mentioned above, has been

designed and is being fabricated in our machine shop. The system is expected to be operational in near future and some research activity in this direction would start during the next year.

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

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The Earth Sciences and Solar System Division comprises of two scientific areas (i) Geocosmophysics, which is the larger of the two areas and involved in studies of terrestrial and extraterrestrial processes and (ii) Continental Palaeoclimate area which focusses mainly on the retrieval of climatic information from the lakes of Kashmir and Gujarat regions during the late Quaternary.

GEOCOSMOPHYSICS

The Area activities pertain to the evolution, in time, of the earth and other solar system objects. Various projects under this broad theme are taken up for detailed study. The area's researches fall under two sub groups, (i) Earth Sciences and (ii) Solar System. In the foregoing sections, highlights are presented first which are followed by all the research activities of the Division, during the reporting period :-

Dating individual unmodified grains in rock systems is the ultimate in geochronology. Lead isotope dating of individual zircon grains using the ion probe has been accomplished. Preliminary studies of zircon grains separated from rocks of the Aravalli mountains in Rajasthan yielded an age of 3.3 billion years (b.y.) with meta-morphic overprinting at 3.0 and 2.6 b.y.

The δD measurements on rings in a 300 year old tree (Abies pindrow) from Kashmir have shown a cooling (by 4-5^{o} C) during the late 16th and early 17th century proving the global character of the little ice age.

Palaeomonsoonal changes have been qualitatively constructed using δ^{13} C in tropical montane peats. It is shown that, during the last glacial maximum, 18 ky ago and during the 4 ky - 8 ky ago, the monsoon was weak as seen by a clear shift towards C4 type of vegetation. Between 8 ky - 12 ky, the monsoon was strong like at present as reflected by a clear shift towards C3 type vegetation.

Studies of nitrogen and noble gas isotopic compositions in interstellar microdiamonds isolated from three primitive meteorites suggest that the magnitude of the nitrogen isotopic anomaly in them varies from one sample to another, which is contrary to previous suggestions for a rather uniform value. It is proposed that interstellar microdiamonds are formed in environments with properties similar to those for local interstellar matter tha* shows a characteristic depletion in the abundance of ^{15}N. Although the exact mechanism for the formation of diamond is still uncertain, our proposal will be consistent with the recent suggestion for the ubiquitous presence of diamond like material in dense molecular cloud based on infra-red observations.

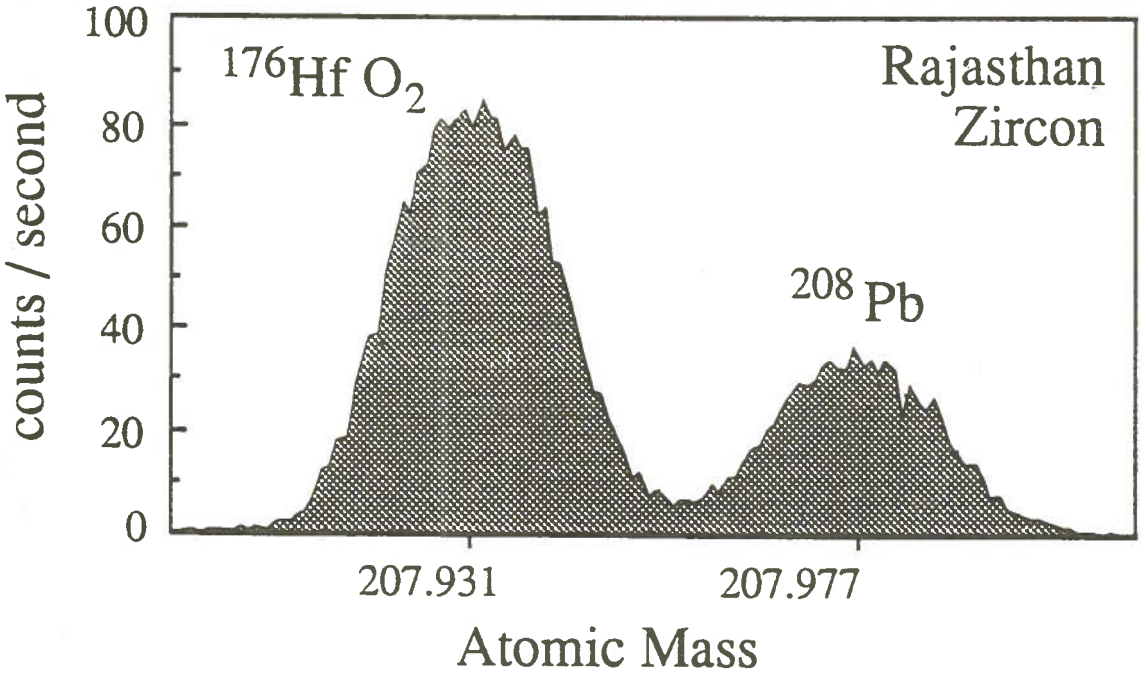
Earth Sciences

In the Earth Sciences group, the major thrust is on three programmes (a) crustal evolution through different time scales, including studies on catastrophic events such as the K/T and P/Tr events,(b) Quaternary climates and tectonics, (c) Aqueous geochemical processes, and geochemical cycles of selected elements.

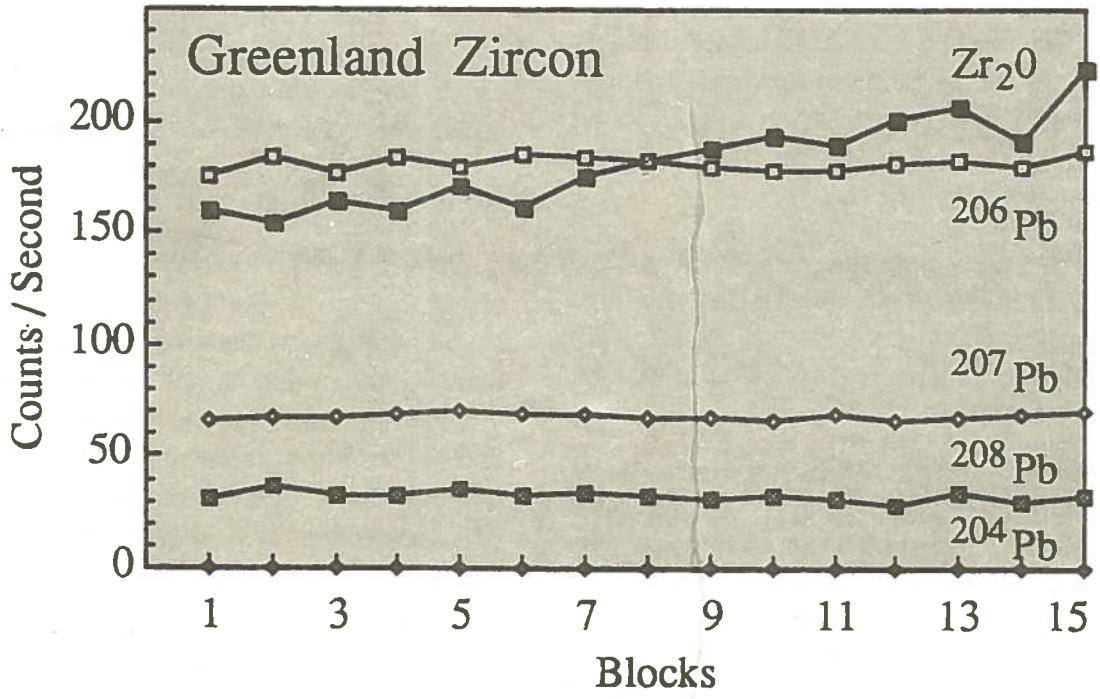
Crustal Evolution

We have been focussing on the determination of the timing and duration of the eruption of major Continental Flood Basalts to assess their role in causing the mass-faunal extinctions at the various boundaries of the geologic record. We had established earlier that the eruption of the Deccan flood basalts do not coincide with the K/T extinctions and that duration of this volcanism is much larger than the required i.e. < 1 m.y. to bring about the K/T extinctions.

We have carried out this year systematic ^{40}Ar- ^{39}Ar chronology of yet another major flood basalt province - the Siberian traps to evaluate



3.1(a) High resolution mass spectrum showing the clearly resolved ^{208}Pb from nearby molecular inference of HfO_2 at a mass resolution of $M/\Delta M = 4000$.



3.1(b) Results from a 15 block (90 minutes run) analysis of a 3.8 Ga Zircon from Greenland. The high stability of the machine during the analysis time is clearly seen.

their relation with the Permo/Triassic boundary event. Our results indicate that basalts erupted very rapidly between 248.1 to 246.5 Ma consistent with the findings of two other international groups involved in the dating of these basalts. The ages when compared with that of the P/Tr event (251.1 ± 3.6 Ma) show that they are compatible, as the chronology of the P/Tr event is not very precisely constrained.

We have also carried out Rb-Sr dating of a few more granitic bodies in the Himalayan collison zone as a part of our major effort to provide a chronology of events during India-Eurasia collison leading to the rise of Himalaya. These plutons display gain/loss of Rb and Sr isotopes and hence do not yield isochrons or ages. The Ar-Ar chronology of these are being attempted.

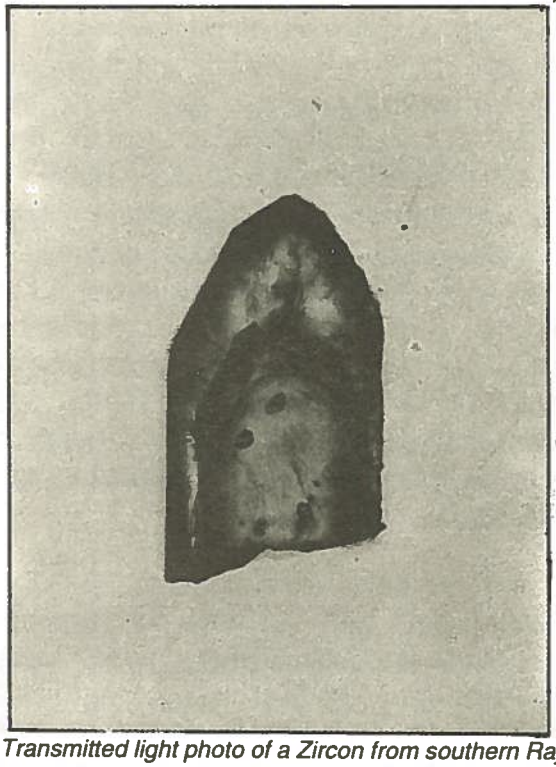
(R. Jadeja, K. Pande, J.R. Trivedi, and T.R. Venkatesan)

Pb Isotope Dating of Single Zircon Grains

For very old (i.e. 3 b.y.) rocks, the problem of geological disturbances suffered by them can affect their age determination. It has,however, been realized that a particular silicate, zircon, ($ZrSiO_4$), that occurs as an accessory mineral in many of the terrestrial rocks, and which is rich in uranium (hundreds of ppm) with high U/Pb ratio can withstand most of the geological disturbances compared to common silicates.Thus, zircon is an ideal phase for dating rocks by the Pb isotope method based on the U-Pb decay scheme where other dating methods may not yield conclusive results.

The ion microprobe, which is capable of analysing isotopic composition of solids with a spatial resolution of a few microns, is ideally suited for such a study as the zircon commonly found in old rocks have sizes of <100 microns. This was first accomplished by a research group at the Australian National University. We have now successfully accomplished Pb-isotopic dating of single zircon grains with the PRL ion microprobe and have reproduced results on two suites of zircons dated at 3.8 and 2.6 b.y. by the Australian group. We are fairly confident that our instrument can be used for dating zircons older than 2 b.y. with good precision. The successful dating of zircons with the PRL ion microprobe was made possible by several modifications introduced in the control and operation of different sub-systems to achieve both the highest possible mass-resolution and transmission in addition to extremely high dynamic stability of the instrument. We present in fig. 3.1a, the high resolution mass-spectra at mass 208 that clearly shows the well-resolved ^{208}Pb peak from the HfO_2 interference. Also shown (Fig. 3.1b)is the result from a typical run that demonstrates the stability of the system. In figure 3.2,is shown the photomicrograph of a zircon with multiple ion microprobe beam spots. The precision that can be achieved at present is ±20 m.y. (2 sigma) for rocks older than 3 b.y.

(J.N. Goswami, N. Sinha and M. Wiedenbeck)



3.2 Transmitted light photo of a Zircon from southern Rajasthan. Age of the grain is 2.9 Ga and length ~150 μm

Boundary Events

Severe climatic changes appear to have occurred at the Cretaceous - Tertiary and Permo-Triassic boundaries resulting in tremendous stress on life on Earth. Studies on the distribution of chemical elements in sediments deposited during the transition hold clues to the cause of extinction and the return of environment at that time.A study was initiated some years ago to determine chemical patterns in sediments deposited during the transition and to infer the cause of extinction from them.Recent results on this ongoing programme are given below.

The K/T transition is characterised by mass extinction of several species on Earth. There is considerable debate as to the cause of this major extinction on the Earth : whether it is triggered by asteroidal or cometary impact or caused by volcanic stress. We have attempted to resolve this through the study of elemental distribution across the boundary.

Chemical clues, based on patterns of about thirty major and trace elements, (including iridium and osmium) existing at and near the K/T boundary (65 Ma ago) in Meghalaya, Koshak (Kazakhastan) and Deccan province were studied. The data show an abrupt and significant increase in concentration of platinum group elements, rare earths and siderophiles at the boundary. The high resolution profile now obtained by us shows a strong short duration Ir peak superimposed on a broad Ir hump lasting over ~10^5 years, Such a profile enables us to distinguish between these three causes and supports the cometary fragmentation model.

The oxygen isotopic ratio [$\delta^{18}O$] and iridium, which are indicators of temperature and of extra terrestrial impact, were measured in sediments from the Koshak section, Kazakhastan with a very high time resolution in Koshak section, Kazakhastan. The results show a rapid excursion (10^3 years) of sea surface temperature at the boundary, associated with the iridium anomaly, where an initial cold pulse is followed by a persistent warm period. With precise phase difference and amplitude of global temperature in relation to impact event thus available, it should be possible to model the response of the Earth to the catastrophic event.

In a parallel study,we measured Ir concentration in the intertrappean sediments to assess the role of Deccan Traps in contributing to the Ir anomaly at the K/T boundary. Our results show a near absence of iridium in the Deccan intertrappean sediments (from Nagpur, Bargi and Jabalpur areas), which suggests that the Deccan Traps cannot explain the observed high Ir levels in the marine K/T sediments. This observation rules out volcanic origin of iridium at the K/T boundary. Another continental intertrappean section of Anjar in Kutch, where dinosaur skeletons have been found, is now being analysed for the platinum group and several other elements. A few more measurements of some elemental profiles and modelling remains to be done to complete this project.Some of this study is being carried out with scientists from the Geological Survey of India.

(N. Bhandari, S.K. Bhattacharya, R.A. Jani, P.N. Shukla and K.M. Suthar)

Quaternary Climates and Tectonics

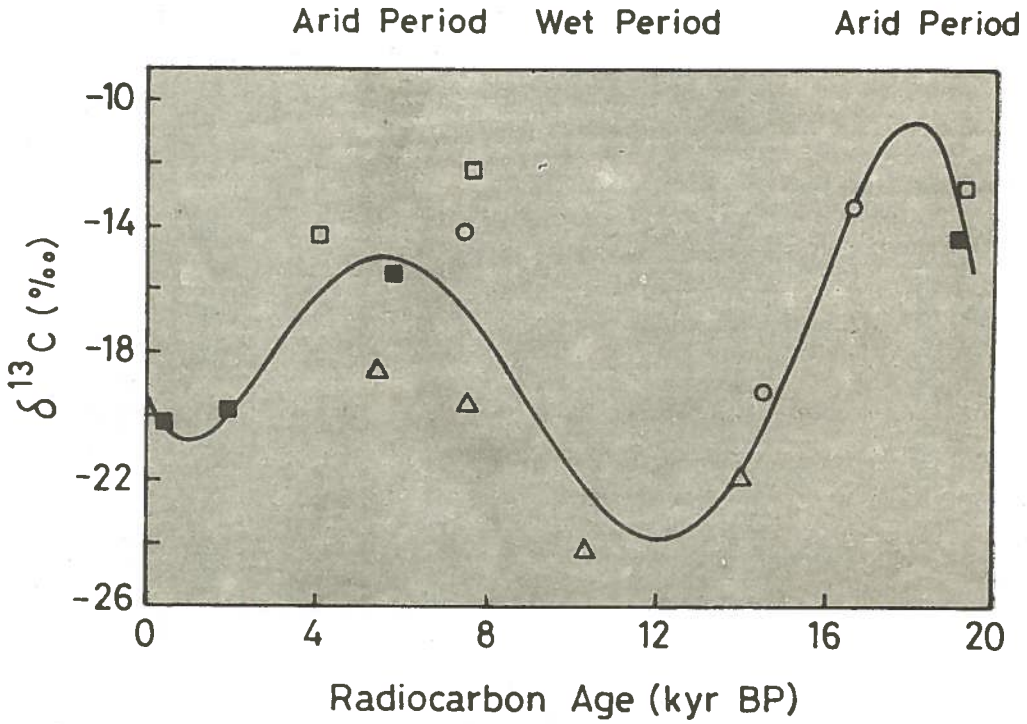
Studies on climatic/environmental changes during the Late Quaternary have assumed greater importance during the last decade, especially after the inception of the IGBP. These studies provide clues to processes contributing to local and global changes. Such information is extremely useful in planning experiments designed to look into and predict future changes. To make significant strides in this direction, high resolution studies of natural records both on land and in the ocean have to be carried out. Our group has been working on problems of past climatic and en-

vironmental changes based on continental and oceanic records.This programme initiated 3-4 years ago as a comprehensive study, aims to get climatic and environmental information from (i) deserts, (ii) glaciers from the Himalayas and the Antarctica, (iii) trees and peat bogs and (iv) marine deposits, corals and sediments. Climate records stored on earth are to some extend affected by tectonics and vice versa. Therefore, as a part of this programme, quaternary tectonic information is also gathered.The programme being, long ranged, a brief account of what has been achieved during the reporting year is described in the following.

Quaternary glaciation in the Central Himalaya: The Milam glacier complex in the Pithoragarh district of the Central Himalaya (Garhwal and Kumaun region) was studied to delineate past glacial advances and retreats. At least three glacial advances could be identified based on lateral morains. The oldest advance is recorded in the form of a lithified lateral morain (tillite) suggesting a depression of equilibrium line altitude by 800m which in turn would mean a temperature decline of 4.8°C (using a lapse rate of 0.6°C/ 100 m for temperate region). These studies, presently in progress, aim at dating the different glacial advances for intercomparison with the other colateral data such as fluvial, aeolian and deep sea records.

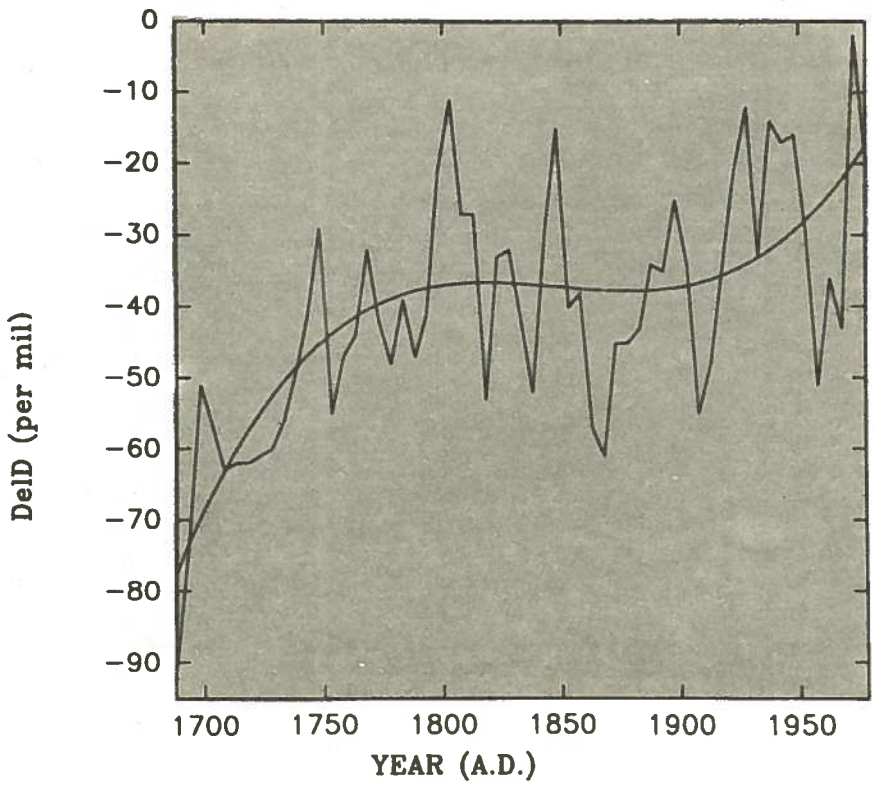
(N. Juyal and R.K. Pant)

Palaeomonsoonal reconstruction using carbon isotopes in peat: Past monsoon variations over south Asia have so far been studied using oxygen isotopes and pollen in deep sea sedi-



3.3 $\delta^{13}C$ variations in peat samples collected from Nilgiris, South India as a function of age. The arid/humid phases are marked above. □ Nanjanad , o Colgrain, Δ Kakathope and ■ Upper Bhawani

ments. We have now shown that carbon isotopic ($\delta^{13}C$) variation in tropical montane peats can be used to qualitatively reconstruct palaeomonsoonal changes. It is known that plants can be classified into two broad categories, C_3 and C_4, which respectively predominate in humid and arid environments. They also have characteristically different $\delta^{13}C$ values because different enzymes participate in their photosynthesis. C_3 plants have a mean $\delta^{13}C$ value of –26 ‰ and C_4, a value of –13‰. Peat deposits are composed of decaying organic matter derived from plants that lived in the past. Therefore the $\delta^{13}C$ profile of a vertical section of peat, the different layers of which are dated using radiocarbon, can provide information on the broad changes of climate in the past, i.e. humid and arid conditions. We, in collaboration with the scientists from the Indian Institute of Science, Bangalore and the Birbal Sahni Institute of Palaeobotany, Lucknow, have collected peat samples from several sites in Nilgiris, South India and have analysed them for their stable carbon isotope ratios and carbon content. Our results (Fig.3.3) show that during the Last Glacial maximum (18,000 years ago) and at 4000-8000 years ago, the monsoon was weak as seen by a clear shift towards C_4 type of vegetation and at 8000-12000 years ago, the monsoon was as strong as today, as reflected by the shift towards C_3 type vegetation. Analysis of peat cores with a higher resolution has also shown evidence for the Mideaval Climatic Optimum (about 1200 A.D.), in this region. This study



3.4 δD variations in a fir tree from Pahalgam, Kashmir, during the past 300 years. The smooth line shows the long term trend .

is being extended back in time to about 100,000 years and the study of oxygen and hydrogen isotopes is also being currently carried out.

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

Evidence for Little Ice Age in Kashmir: One of the key questions under the International Geosphere Biosphere Programme is the determination of the spatial extent of short term abrupt climatic changes, are they regional or global in nature? One such event is the Little Ice Age, which has been reported in Europe, during 1400-1725 A.D. To look for records of such short term climatic events, we have analysed the hydrogen isotope ratios(δD) in cellulose derived from a 300 year old tree collected from Kashmir, India. This species (Abies pindrow) has been earlier shown by us to preserve temperature signals in its δ D. Our results show (Fig. 3.4) that there was indeed a cooler period in the late 1600's and early 1700's. The temperature reduction was of the order of 4 to 5^{o}C in the altitude of about 3000 m.

(J.T. Padia and R. Ramesh)

Deserts : A significant part of this year's study pertained to tectonics, in addition to the programme to determine the chronology of events (such as periods of major desertification) recorded in the sand columns of the Thar desert using the Luminescence dating method and their relation to global climate changes. Our group has made considerable advances in the development of appropriate techniques to date these sand grains. Also the fluvially transported river sediments and lake sediments bordering the Thar have been taken up for the dating of lacustrine sequences using TL. In the case of proximally transported fluvial sediments, several palaeofan deposits of river Sabarmati were dated and concordance of repeat analyses of different samples from the same horizon gave confidence on the partial bleach methodology adopted by us. Remote sensing, geomorphological, altimetric and sedimentological studies by Dr. B.K. Sarin and Prof. S.K. Tandon of Delhi University indicated that the present flow direction of the river Sabarmati is almost orthogonal to the region slope, indicating an adjustment of the river flow direction to the neotectonic stress field. Our studies suggest an age of < 50 ka for this event.

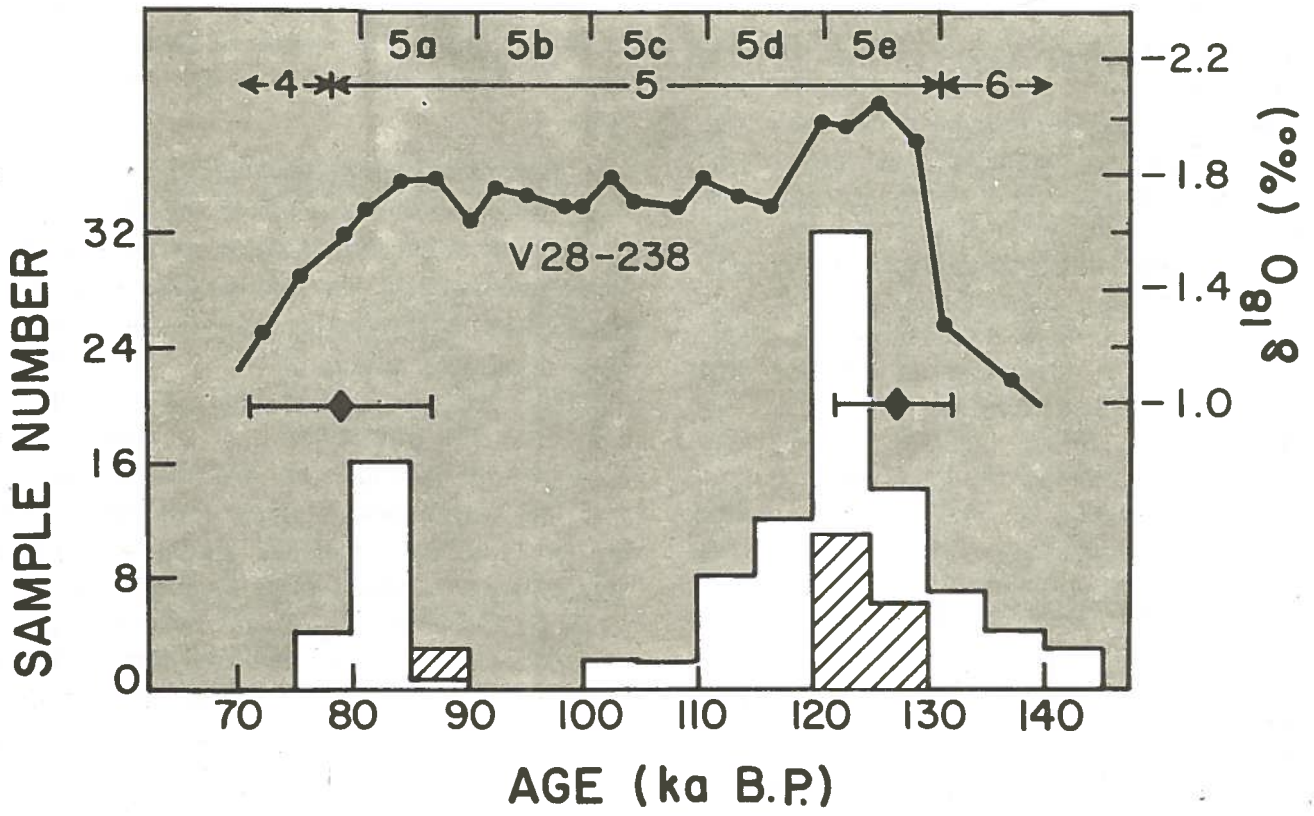
In another study, the feasibility of dating lake sediments of the Thar and its margins was investigated, three lakes have been taken up this year.

In yet another study, in collaboration with Prof. K.S. Valdiya of Kumaun University, Nainital, the feasibility of dating neotectonic movements and Palaeoearthquakes via Luminescence was attempted through the analysis of fault gouge and the soils developed over large scale tectonic-movement-induced-debris. Two fault gouge samples, 6 km apart from the Nainital fault yielded notional TL ages of 33 ka and 38 ka. Coupled to the fact that the parent rocks of upper Proterozoic age, the notional ages indicate a definite "Thermal zeroing event" consequence to faulting movement. A supporting evidence is also provided by the inferred antiquity of Nainital lake (formed due to neotectonic movement) of ~ 38 ka, which closely matches the TL age of fault gouge. Further, two samples from buried soils of unpaired fluvio-lacustrine terraces (E, N-E of Bhawani) gave stratigraphically consistent partial bleach ages of 3.7 ka and 4 ka respectively. It appears likely that such studies as these will prove useful to estimate palaeo-earthquake frequency.

Other collaborators in all these studies include Dr. R.P. Dhir of CAZRI, Jodhpur, Prof. S.N. Rajaguru of Deccan College, Dr. M.D. Kajale, Poona University, Pune and Dr. S. K. Gupta and Miss S. Prasad from the Continental Palaeoclimate Studies Area of our Division.

(D. Banerjee, R. Ramesh, N.Someshwara Rao and A.K. Singhvi)

Sea levels from Saurashtra coast - role of tectonism: Changes in sea level is another manifestation of climate change. However, sea level changes can also result from local tectonic events also. One approach is to ascertain if an



3.5 Correlation of sea level data with deep sea oxygen isotope record. Top shows the $\delta^{18}O$ curve from core V 28-238 (Shackleton and Opdyke, 1973). Histogram shows sample numbers vs U/Th age in ka (open and hetched areas represent alfa and mass spectrometric age determinations respectively).Saurashtra oyster ages are represented by filled diamonds with error bars

observed sea level change results from global climatic event, is to check if it is synchronous with the global sea level record. Three palaeo sea levels were identified by us along the Saurashtra coast as a result of intensive field investigations and radiometric dating of oysters representing past high sea stands. The U/Th and ^{14}C ages of the oysters confirm our earlier observations that the Saurashtra coast has undergone differential land movement during the late Quaternary. Fig. 3.5 compares radiometric dates from Saurashtra coast with the deep sea oxygen isotope records and other dated sea levels from various parts of the world.

(R. Bhushan, N. Juyal, R.K. Pant and B.L.K. Somayajulu)

Aqueous Geochemistry

Under this heading, we describe programmes in glaciers, rivers and oceans. These studies relate to processes occurring in these reservoirs, such as the deposition and dynamics of snow/ice in glaciers, weathering and transport of dissolved

constituents by major rivers and adsorption-desorption kinetics and water circulation in the oceans.

Glaciological Studies : A systematic study of the chemical composition of snow and firn from a shallow core, surface ice and of meltwater samples collected from the Chhota Shigri glacier, Central Himalaya, was carried out.The average concentrations of Na and Cl in snow are 402 and 753 μgl^{-1} , respectively, whereas those in older surface ice are relatively lower, 185 μgl^{-1} and 375 μgl^{-1} , respectively. The average Cl/Na weight ratio in these samples is 1.9, quite similar to that in sea salts suggesting that both Cl and Na are predominantly of marine origin. The concentrations of other major ions such as K , Mg , Ca, NO_3 and SO_4 in snow and ice samples are generally less than 1 mg l^{-1} . The major ion concentrations, when normalized to Na, indicate that the abundances of K and Ca are dominated by terrestrial sources whereas Mg appears to have both marine and terrestrial sources. Based on the seasonal variations of Na and Cl concentrations observed in the ice core samples, an approximate accumulation rate at the core site has been estimated to be 1.6 m $year^{-1}$ (640 kg m^{-2} $year^{-1}$).

In another study, the concentration of radionuclides ^{32}Si, ^{7}Be, ^{210}Pb and ^{137}Cs were measured in snow samples from the shelf ice near the Indian station, Dakshin Gangotri, East Antarctica. The annual fallout of cosmic-ray produced ^{32}Si - the first measurement in Antarctica - is determined to be 2.34×10^{-5} dpm cm^{-2} y^{-1} which corresponds to a global production rate of ^{32}Si of 0.75×10^{-4} atoms cm^{-2} sec^{-1} (based on ^{32}Si half life of 140 y). The fallout of the other natural radionuclides ^{7}Be and ^{210}Pb are 4.2 and 1.86×10^{-2} dpm cm^{-2} y^{-1} , respectively. Based on the depth profile of ^{210}Pb and ^{137}Cs concentrations in the shallow ice core samples, the accumulation rate of ice is to be 13.5 g $cm^{-2}y^{-1}$ (0.3 m y^{-1}) over the past few decades.

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

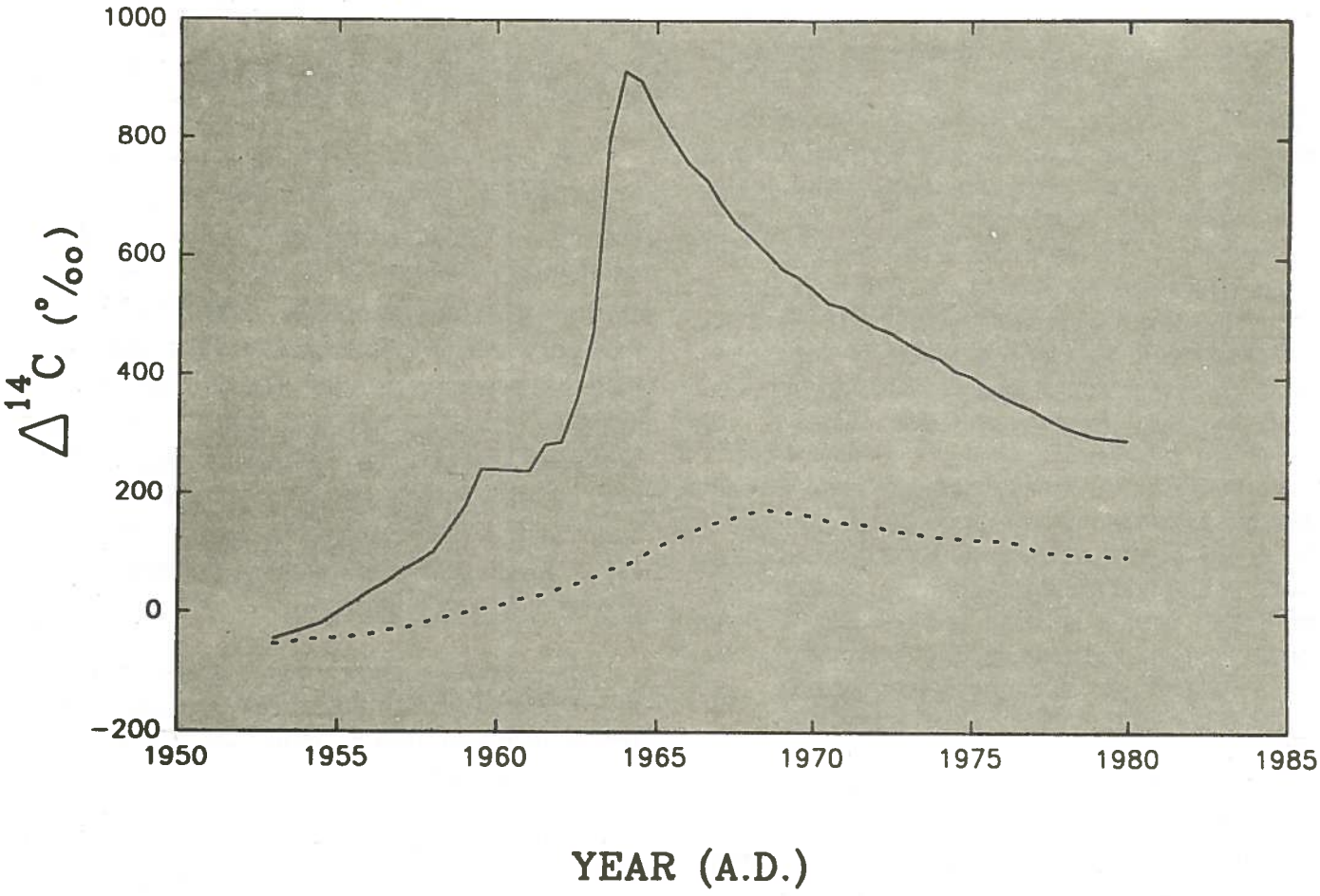
Indus water chemistry and weathering in the Himalayas: Extensive studies of major ion chemistry and isotope systematics of Sr and U have been carried out on the Indus River and its tributaries to evaluate (i) weathering controls on the major ion chemistry and (ii) the role of Indus in contributing to the evolution of U concentration and Sr isotopes in the ocean since the Cenozoic.

The results show that the major ion chemistry is dominated by carbonate weathering similar to that in the Ganga-Brahmaputra. In the upper reaches, however, there are signatures of major ion input from thermal springs. The $^{87}Sr/^{86}Sr$ of the Indus near its mouth is only 0.7111 much less than that observed for the Ganga Brahmaputra systems, reflecting dominant supply from carbonates. Similar to the Ganga-Brahmaputra, the uranium concentration in the Indus waters is also quite high, a few micrograms per liter. Weathering of black shales/granites are probably the source of this high uranium.

Our studies show that rivers draining the Precambrian granites/gneises of the Himalaya (Ganga and its tributaries and some of the tributaries of the Indus) have both high Sr concentration and $^{87}Sr/^{86}Sr$. They are unique in this respect. Of the three major rivers studied, the $^{87}Sr/^{86}Sr$ decrease as Ganga > Brahmaputra > Indus and reflect the lithology of the drainage basins.The Himalayan Orogeny, thus, has played a key role in the marine geochemical cycles of some of the LIL (Large Ion Lithophile) elements. This study was carried out in collaboration with Dr. K.K. Sharma of the Wadia Institute of Himalayan Geology, Dehradun.

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

Air-Sea CO_2 exchange using Corals : It is important to know how the excess CO_2 injected into the atmosphere by fossil fuel combustion is taken up by the oceans. Bomb produced radiocarbon in ocean water can be used as a



3.6 Δ^{14} C variations in the atmosphere (northern hemisphere, solid line) and in the coral from Gulf of Kutch

tracer to determine the CO_2 exchange flux. Using corals as a monitor of surface ocean radiocarbon, we have determined the CO_2 exchange flux.Towards this, we have analysed $\delta^{14}C$ in the annual bands of a 40 year old coral (1953-1991) of the genus Faviae collected from Pirotan Island, Gulf of Kutch. This $\delta^{14}C$ time series in the coral gives us the time evolution of surface ocean radiocarbon activity in this region (Fig. 3.6). The temporal changes in the radiocarbon activity in the atmosphere can be obtained by measuring the $\delta^{14}C$ of the annual rings in trees. The average time series for the Northern hemisphere (available from the literature) is also shown in Fig. 3.6.

These data are modelled and the exchange flux is estimated to be about 11 moles/m^2 year, comparable to the values obtained from the Pacific and Atlantic oceans. This value also tallies with the one obtained by using the linear empirical relationship of wind speed and CO_2 invasion flux.

Denitrification in the Eastern Arabian Sea : It is well known that the Arabian Sea is characterized by a well developed denitrication layer in the intermediate depths. The source of carbon to maintain this denitrification is debated; one candidate is diffusion from the margin sediments. We have attempted place constraints on the diffusive flux in DOC needed to maintain the denitrification layer. Towards this, the horizontal eddy diffusivity was measured using Ra isotopes.

The $^{228}Ra/^{226}Ra$ activity ratios (henceforth denoted as [228/226]) have been measured both at surface and at 300 m depth as a function of distance from the Western Continental margins of India to the open Arabian Sea (between 15 ^{o}N-21^{o} N). A two dimensional eddy diffusion model is used to fit the measured [228/226] profiles to deduce horizontal eddy diffusivities in both zonal (towards open ocean) and meridional (equator ward) directions. These range between $1.3x10^6$ and $3.1x10^6$ cm ^{2}/sec. Assuming that the organic matter rich and deeply anoxic continental margin sediments at ~ 300 m depth can be a source of organic C to the core of the denitrification layer and that the deficit flux in the carbon budget can be covered by this supply, the required gradient dC/dZ in DOC content of waters from coast to open Arabian sea is computed using the K_x value. The required gradient is computed to be 4 μ mol. dm $^{-3}$ /100 km which is within the error associated with DOC measurements and appears reasonable. This preliminary estimate warrants detailed measurements of both POC and DOC profiles alongwith Ra isotope data, which are in progress.

Recent sedimentary records from the arabian sea: An attempt is made to understand the redox conditions in the north-eastern continental margins of the Arabian sea during the past few centuries based on elemental abundances in short undisturbed sediment cores. Towards this, the sediment cores were dated using ^{210}Pb excess method. The proxy indicators chosen for productivity and associated redox changes are $CaCO_3$, organic matter (OM), Mn and U alongwith major elements Fe and Al. These alongwith data on gravity cores from the same region (published earlier) suggest the following:

South of 21^{o} N, at ~ 300 m water depth the sediment-water interface region had been anoxic during the time span represented by the presently studied cores viz. ~700 y as evidenced by low Mn/Al ($< 0.7 x10^{-2}$) and high U/Al ($> 10^{-4}$) weight ratios. In some adjacent deep water regions, however, the environment turned oxic around ~ 200y BP. Whereas both Mn and Ra are lost to the overlying waters in the anoxic regions (depth ~ 340m), in the deep water (~ 2500 m) cores, the Mn that diffused from deeper sections appears to have mineralised at the sediment-water-interface. Studies of this type on long undisturbed cores from the margins of the Arabian Sea and the Bay of Bengal, involving several proxies and geochronology by more than one method are needed to understand short term environmental changes of the recent past with high resolution.

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

Solar System Studies

Microdiamonds, refractory inclusions in primitive meteorites have attracted our attention due to the early solar system and pre-solar records contained in such grains.

In our continuing study of interstellar grains in meteorites, we have now analysed microdiamonds isolated from three different types of meteorites. Two of these, Murchison and Efremovka, belong to two different sub-classes of carbonaceous chondrite while the third,

Krymka, is an unequilibrated ordinary chondrite. Mass-spectrometric analysis of nitrogen and noble gases were carried out by extracting gas from these samples by combustion in 3 torr oxygen at low temperature (upto 700°C) and by pyrolysis at higher temperatures. The main aim is to unambiguously establish the association between anomalous nitrogen and xenon isotopic features in interstellar diamonds and to look for possible differences in the characteristics of the diamonds separated from the three different meteorite types. The principal results obtained in the three samples are as follows:

Murchison

About 60 to 90% of all the gases are released during the low temperature step, which is characterized by the presence of a xenon isotopic anomaly with enrichment in both light (^{126,128}Xe) and heavy (^{134,136}Xe) isotopes, the so called Xe-HL, and a depletion in the ^{15}N/ ^{14}N ratio by about 33% below the atmospheric value. The neon isotopic composition show the characteristic planetary value (20/22 = 8.46; 21/22= 0.0348). The next release peak is seen at the 1200°C pyrolysis step which is characterized by an even higher depletion of ^{15}N (^{15}N/ ^{14}N value ~ 60% below atmospheric) a neon component enriched in ^{24}Ne (Ne-E) and a xenon component enriched in isotopes (e.g. ^{128}Xe) produced by slow-neutron capture process (Xe- S). While the low temperature features are characteristic of interstellar diamonds, the high temperature features resemble those of interstellar SiC and suggest their presence as a minor constituent of the Murchison microdiamond separate.

Efremovka

About 60% and 40% of the samples are combusted respectively during the low temperature step. Although the amounts of gas released at these temperature steps show the Xe-HL pattern while the maximum depletion in ^{15}N/ ^{14}N ratio (w.r.t. atmospheric value) is about 29% in the 600°C step which is distinctly different from the results obtained from Murchison microdiamonds. The peak release during the pyrolysis step show an admixture of Ne-E, Xe-S and Kr-S signals, that are typical of SiC, and in addition has a much lower depletion (~13%) in ^{15}N/ ^{14}N ratio compared to Murchison.The difference between the Murchison and Efremovka data are suggestive of the presence of an additional interstellar component (apart from diamond and SiC) in the analysed sample. One possibility is graphite which has the right combustion temperature and may be the carrier of the additional isotopic anomalies seen in this sample.

Krymka

The extremely small sample amount (0.01 mg) allowed us to analyse in detail the isotopic composition of only the major release during the low temperature step. It is characterized by a Xe-HL signature, planetary neon composition and about 22% depletion in the ^{15}N/ ^{14}N ratio.One major accomplishment of the present study is establishing clearly the association of Xe-HL signature, and a depletion in ^{15}N in microdiamonds. The co-release of these anomalies at the same temperature uniquely establish microdiamond as the host phase for these anomalies. The present experiment where both are measured simultaneously proves this association unequivocally. A second interesting feature is the variability in ^{15}N depletion in microdiamonds. Earlier experiments suggested a unique value of about 31% for the depletion of ^{15}N / ^{14}N ratio compared to atmospheric value in interstellar microdiamond. Our results calls into question this proposition which is plausible according to recent astronomical observations.

Grosnaja Meteorite

The observation of extreme variations in ^{26}Mg excess in refractory inclusions from primitive

meteorites led to the suggestion for a heterogeneous distribution of ^{26}Al, which decays to ^{26}Mg with a half life of $7x10^{5}$ years in the solar nebula. We have now analysed a set of petrographically altered refractory inclusions from the Grosnaya meteorite to further investigate this problem.The analysed samples represent three different inclusion types : compact type A (melilite-rich), type B (pyroxene-rich) and type C (anorthite- rich). Secondary alteration of the inclusions are evident from the presence of Na-rich plagioclase, garnet and calcite. The isotopic data for the type A inclusion show absence of excess ^{26}Mg. A subset of the data for type B inclusion yields initial $^{26}Al/^{27}Al$ ratio of ~ $2x10^{-5}$, although no well-behaved systematic trend can be discerned if one considers the complete data set. Data for anorthites in the type C inclusion yield initial ratio in the range of $(2\text{-}3.3)x10^{-6}$. Though the above data can be considered as a reflection of extreme heterogeneity in ^{26}Al distribution in the region of formation of the Grosnaja inclusions, we believe that the variations simply reflect redistribution of magnesium isotopes during post-formation processes affecting those inclusions. The affect of such post-formation process is clearly indicated by the presence of secondary minerals (e.g. garnet, calcite) in these inclusions. The large variability in the magnitude of excess ^{26}Mg, seen primarily in petrographically altered inclusions, and rarely in refractory inclusions (e.g. those from Efremovka) substantiate our conclusion that this variability is not a heterogeneous distribution of ^{26}Al in the solar nebula.

Isotopic Studies of Chromium-rich Objects in Chondritic Meteorites

The Ca-Al rich refractory inclusions (CAIs) in meteorites are considered to be some of the first solids to have formed in the solar system. The search for other refractory objects that have formed early in the solar system history led to identification of plagioclase-olivine-rich inclusions (POIs) and refractory element enriched (Al-rich) chondrules, that have predated the more common silicate chondrules found in the chondrites. Recently another type of objects, the Cr-rich inclusions and chondrules have been documented in several H- chondrites which may be a sub-class of a more general population of Al-Cr-rich objects.The chromium-rich inclusions and chondrules consist of chromite and sodic plagioclase with ilmenite, pyroxene and phosphate occurring as accessory phases. Though the genesis and their interrelationship of these objects are not clearly understood, condensation from nebular gas of non-solar composition, gas phase metasomatism and oxidisation of metal phases are some of the proposed mechanisms for the formation of the chromite phases. We have carried out ion microprobe studies of isotopic compositions of magnesium, chromium and iron in a set of Cr-rich objects in the Raguli meteorite (a H_3

3.7 Euhedral grains of chromite from Chromite-rich chondrule of Raguli meteorite

chondrite) to further address these questions. The analysed phases include two chromite-rich chondrules, one of which contains two large euhedral grains of chromite (Fig. 3.7), two chromite -rich inclusions and isolated chromite grains in the matrix.

Magnesium isotopic compositions of plagioclase phases in these objects were measured to look for possible presence of excess ^{26}Mg. Contribution from chromite towards the magnesium signal made these measurements difficult and a relatively clean signal could be seen only for the plagioclase in one of the chondrules (measured $^{27}Al + {}^{24}Mg = 52$). No evidence for excess ^{26}Mg due to decay of now extinct ^{26}Al was found. The results suggest that the precursor material from which the Cr-rich objects were formed had nearly unfractionated magnesium and chromium isotopic compositions and also the process(es) leading to the formation of these objects did not result in any detectable isotopic fractionation in the chromite phases.

Mass Spectrometry : S.V.S. Murty

Ion Probe Studies : M.P.Deomurari, J.N Goswami S.Sahijpal, V.G. Shah,R. Srinivasan

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1. Bhandari, N., Gupta, M. and Shukla, P.N., "Dec can volcanic contribution of Ir and other trace elements near the K/T boundary" Chem. Geol., **100**, 486, (1992).
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CONTINENTAL PALAEOCLIMATE STUDIES

The major programme of the group is the reconstruction of climatic conditions of the past (10-100) thousand years archived in modern and relic lakes. Towards this, sediment cores have been collected from the Mansar lake in the Jammu region. Radiocarbon measurements suggest that the core can provide climatic data to about 6 ka.

A 50m core from lake Nal Sarovar located in a climatically sensitive belt on the fringe of the Thar desert offers a good opportunity to reconstruct a continuous record of past climate changes since the last glaciation. A number of studies are being planned on this core. Preliminary results on modern sedimentation indicate that the bomb produced ^{137}Cs is confined to top six cms., suggesting that recent sediment accumulation rate is < 0.2 cm/yr.

A major effort of the group went into the installation of the new Quantulus Liquid Scintillation Spectrometer. The system is now fully operational and has a background of 0.35 counts per minute for radiocarbon. Such low background will enable us to date samples as old as 40,000 years.

In the modelling studies it has been shown that as such the eccentricity signal in the solar insolation spectrum is too weak to explain the observed 100 kyr dominant periodicity in the geological record. However, a non-linear operation, e.g. squaring the insolation function can explain more than 70% of the observed variance of the isotopic record.

Climatic Studies on Mansar Lake Sediments

As part of the continuing programme on reconstruction of climatic condition in Indian subcontinent, several long sedimentary sequences from lakes (including relict) in presently different geomorphic and climatic regions were sampled using indigenously developed Mackereth corer. Studies on cores from Mansar lake, Jammu, indicated that the average accumulation rate based on ^{210}Pb and ^{14}C assays have remained constant for the past 5000 years. Detailed mineral magnetic analyses indicate low anthropogenic contribution to the lake and a nearly constant climatic regime for the last 2500 years. Further sedimentological, stable isotopic and geochemical studies are being planned.

(D.P. Agrawal, R.D. Deshpande, Sheela Kusumgar, C. Sharma and M.G. Yadava)

Palaeoenvironmental Reconstruction from Nal Sarovar

Nal Sarovar is a 100km^2 shallow closed basin lake on the western fringe of the Cambay basin. A 50 m long core was successfully raised from the lake bottom with the help of the Directorate of Geology and Mining , Government of Gujarat. The objective of this study is to quantitatively estimate past climatic changes, with an absolute chronological framework.

The stratigraphy of the section as observed in the field shows three distinct layers: (0-3) m Grey mud rich in shells and organic debris; 3-18 m coarse to fine sand with gypsum crystals and $CaCO_3$ nodules; 18-53m (bottom) brown clay with occasional fine to coarse sand layers, rich in $CaCO_3$ nodules.

Several lines of investigations are in progress and preliminary results are listed below.

a. Oxygen and Carbon isotopes of $CaCO_3$ nodules in the depth range of 18-50 m indicate that these may have precipitated under shallow lake to sub-areal conditions.

b. TL studies on the silt grains from the layer between 4-18 m suggest that old rock fragments that comprised the source material were not exposed to solar radiation during their transit to the core location in the Nal Sarovar and may have possibly been transported by flash floods.

c. ^{210}Pb and ^{137}Cs dating of the topmost part of the core suggested that (i) layers upto 6 cm depth are more or less uniformly mixed and, (ii) the sedimentation rate is about 2 mm/yr and that upper 20 cm is about 100 yr old. These results limit the achievable resolution of palaeoclimatic signatures as reconstructed from analyses of the core to 30 yr. Radiocarbon dating of a sample from 293-300 cm depth gave an age of 1180 ± 210 yrs before present (B.P).

(N. Bhandari, S.K. Bhattacharya, S.K. Gupta, N. Juyal, S. Kusumgar, S. Prasad, P. Sharma, A.K. Singhvi and B.L.K. Somayajulu)

Highlights of Radiocarbon Dating: National Facility

The group continued to serve as a National Facility for radiocarbon dating and about 50 dates were measured. The following are some of the important results obtained by us:

1. For the first time south Indian ash mounds associated with Neolithic phase have been dated to ca.8000 B.P. Such an early date raises the possibilities of dating the earliest domestication of plants and animals in India.

2. Evidence of copper mining by early human cultures dating back to 1200 yr B.C. has been found in Udaipur. Old working of copper mines in Dariba area of Udaipur district can now be dated to about 1200 B.C. indicating that these mines have been exploited since the Chalcolithic period.

3. The carbonate Kankar strata from the Gangetic alluvium, U.P.show date in two ranges, at depth 20m, 12 kyrs and at depth less than 10m, 7 kyrs. This probably represents lower precipitation and lowering of the groundwater table due to weakening of southwest monsoon. In Rajasthan these periods are associated with relatively arid fluctuations.

4. Flood events of Narmada dates between 840 and 400 years B.P. This flood level is about 25m above the bed level of Narmada. This flood could have a relationship with the medieval warming.

(D.P. Agrawal, Sheela Kusumgar and M.G. Yadava)

Snowline Depression over Tibet during Last Ice Age

Using ice core isotopic data of the Dunde ice cap in Tibet, a temperature drop of only 4-6 degrees is indicated during the last 40 kyrs. which translates to a snowline (or ELA) depression of 700-800 m, provided opposing effect of the possible decrease in precipitation was not considered.

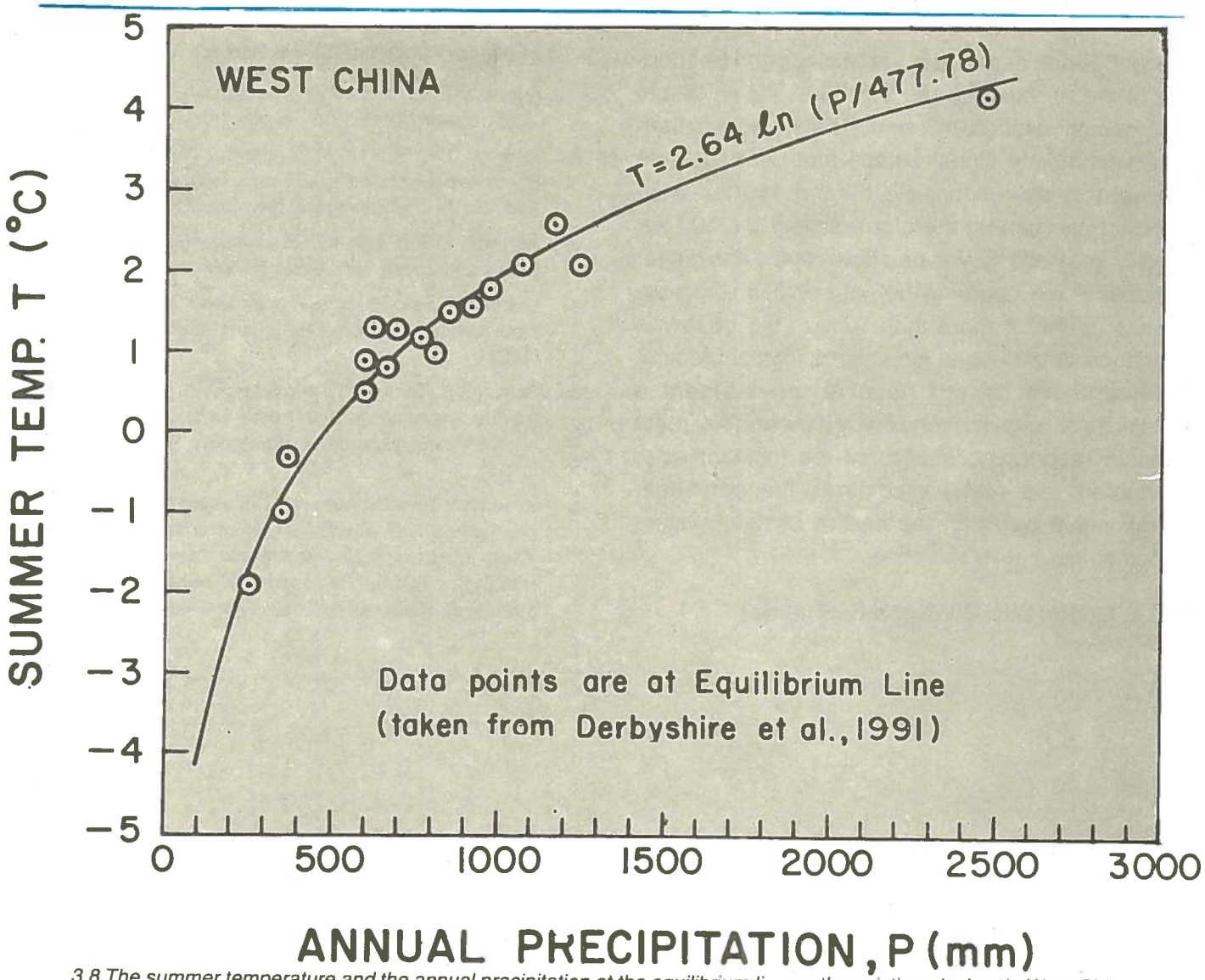
We have now shown that the following logarithmic relation fits the data of summer temperature (T) and annual precipitation (P) at equlibrium line on the existing glaciers in Tibet and around (Fig.3.8)

$$T = 2.64 \ln (P/477.78) \qquad (1)$$

or

$$dT = 2.64 (dP/P) \qquad (2)$$

from which it follows that for every 10 % decrease in precipitation a temperature drop of 0.26 degree C in the summer temperature is required to maintain the position of ELA. Alternatively, there will be



3.8 The summer temperature and the annual precipitation at the equilibrium line on the existing glaciers in West China, showing a logarithmic relationship

an ELA rise of 38 m for an assumed lapse rate of – 0.7 degree C/100 m if the precipitation decrease was not accompanied by atmospheric cooling.

In central parts of Tibet, a change in annual precipitation from the present day average of 400 mm/yr to a mere 100 mm/yr during the last ice age has been indicated by several independent studies. Use of equation (2) above for such a precipitation change requires a drop of 3.6 degree C to maintain ELA at present day level. So that only 0.4 degree to 2.4 degree C estimated from $\delta^{18}O$ shifts would be effective in lowering the snowline on Tibetan Plateau during the Last Ice Age. This translates to a marginal snowline depression 50-350 m for the central plateau regions.

(S.K. Gupta and P. Sharma)

Late Quaternary Glaciation and Genesis of Ice Ages

The observed dominant 100 kyr periodicity in the late Quaternary palaeoclimatic record has

recently been ascribed to variations in the frequency of the obliquity cycle. We have shown that in the insolation record this signal is even weaker than the eccentricity signal (which has been hitherto thought to be responsible for the 100 kyr periodicity) and cannot therefore explain the 100 kyr cycle. We have, however, shown that a non- linear operation, e.g. squaring the input isolation function, can account for more than 70% of the observed variance of the ocean ice volume isotopic record. Although we do not have at the moment a geophysical explanation of why the earth's climate should respond to square of the incident solar radiation, our result reconfirms the non-linear relationship between the earth's climate system and the input solar radiation.

(S.K. Gupta, S.K. Shah and P. Sharma)

List of Papers Published During 1992-93

1. Agrawal, D.P., Kusumgar Sheela and Yadava, M.G., "Radiocarbon Date List-VI", Radiocarbon, **33**, 329 (1992).
2. Agrawal,D.P., "The Other Dimensions of Archaeology" in South Asian Archaeology Studies, (ed). G. Possehl, Oxford and IBH Publishing Co. New Delhi, (1992).
3. Agrawal, D.P., Man and Environment Through Ages, Books and Books, New Delhi, (1992).
4. Gupta, S.K. and Sharma, P.,"Snowline Depression over Tibet During the Last Ice Age", Current Science, **63**, 393 (1992).
5. Gupta, S.K., Sharma, P. and Shah, S.K., "Constraints on the Thickness of Ice Sheet over Tibet During the Last 40,000 years", Journal of Quaternary Science, **7**, 283 (1993).
6. Kusumgar Sheela, Agrawal, D.P., Narendra Bhandari, Deshpande, R.D., Raina Alok, Sharma Chhemendra and Yadava, M.G.," Lake sediments from the Kashmir Himalayas: Inverted Radiocarbon Chronology and its Implications", Radiocarbon, **34**, 561 (1992).

The research activities of the Theoretical Physics Division can be broadly divided into Macroscopic and Microscopic physics. The research programmes in Astrophysics, Meteorology and Climate Studies and Plasma Physics belong to the former category while research in Atomic and Molecular Physics, Foundation of Quantum Mechanics, Nuclear Physics and Particle Physics belong to the domain of Microphysics. Some of the highlights of the work done during the past one year are given below.

MACROSCOPIC PHYSICS

Astrophysics

One of the most interesting studies undertaken deals with the identification and classification of large scale structures, from amongst the numerous objects in the CFA survey, which enlist over 40,000 sources. The technique is based on calculating the expectation of structures like clusters and voids from a random background distribution of the galaxies using the three parameters viz., the angular coordinates and the radial velocity. Another important study underway deals with the analysis of possible equilibrium configuration for rotating ultra compact bodies wherein the pressure gradient forces acting outwards would balance both the gravitation and centrifugal forces acting inwards (due to centrifugal reversal effect of general relativity). As such equilibrium configuration differ from Newtonian figures of equilibrium, it is very much necessary to understand the possible revival of spherical objects from spheroidal ones that could arise due to the maximum of ellipticity attained by the collapsing configurations.

Meteorology and Climate Studies

The recently launched International Geosphere Biosphere Programme (IGBP) addresses itself to problems of global change due to natural and/or anthropogenic causes. An important and challenging aspect of IGBP is modelling of global changes in general and climate changes in particular. In this context, we have initiated a major new programme in climate modelling during this year under the ISRO-GBP. Our main objective in this is to understand the causes and mechanisms of variability of monsoon and tropical circulations on the interannual and decadal timescales. Towards achieving this objective, we have begun work during the year on the development of a global climate model. This will be an atmosphere-ocean coupled model using the spectral method and will be based on the low-resolution atmospheric model developed at PRL earlier. Some of the important characterisation of this new model will be a high resolution of 35-waves, orography, a fairly realistic treatment of heating due to cumulus clouds by Kuo's scheme and a mixed layer ocean model. During this year we have successfully enhanced the resolution and validated the model.

Plasma Physics

Plasmas in laboratory as well as in space support many waves and instabilities. Very often one observes them in turbulent states which by definition are nonlinear effects. Naturally, the study of nonlinear waves and instabilities has become an important part of the theoretical plasma physics programme. With the help of nonlinear techniques, it has been possible to demonstrate the different stages of nonlinear evolution of different waves. In particular, it is shown recently how Alfvén waves become chaotic at later stages of evolution when the driver is strong.

Recently, the study of dusty plasma has attracted great attention in view of possible application of such studies in space plasma environments such as cometary tails, planetary ring systems, interstellar clouds etc. A new programme has been initiated during the year to study low frequency waves in dusty plasmas consisting of electrons, ions and dust particles. A new kind of magneto-acoustic wave called "Dust-

magnetoacoustic Wave" is found when the ion fluid is not frozen to magnetic field lines. Convective sales and Alfvén vortices are shown to be generated in nonuniform dusty plasma in a magnetic field and these should be useful in understanding the generation of turbulence in dusty plasmas that often exist in cometary tails and interstellar clouds.

A different idea for the generation of plasma irregularities in the ionospheric plasma, particularly in the auroral region of ionosphere is proposed on the basis of an instability due to presence of equilibrium density and temperature gradients in a weakly ionized magnetoplasma. The instability is capable of producing irregularities with velocity larger than ion- acoustic velocity and may be important for some observed phenomena of auroral electrojet irregularities with unusual spectral signature that has been identified as type 4 spectrum of radar aurora.

MICROSCOPIC PHYSICS

Particles and Fields

The electroweak interactions are described by a broken SU(2) x U(1) symmetry. The breaking of this symmetry is achieved with the help of a spin zero particle conventionally known as Higgs boson. This particle has not been found experimentally. We have shown that signatures of this particle could get drastically modified in many models which try to generate a non-zero mass for the neutrino. Detailed analysis of these signatures in the light of already available data in $e^+ e^-$ collisions at CERN was made this year. The same data were also used to constrain other extensions of SU(2) x U(1) model. Specifically, models with extra gauge bosons and supersymmetric grand unified models were extensively analysed.

In the currently popular and experimentally well tested scenario, the strong interactions are described in terms of forces acting between the basic constituents of matter called quarks and gluons. This picture predicts the existence of a new phase of matter at high temperature and density. The mechanism of formation of this quark-gluon plasma phase is not well understood. A model calculation was performed which tries to describe formation of quark antiquark pairs. It was shown that the basic non-abelian nature of interactions could play an important role in the formation of $q\bar{q}$ pairs.

Atomic and Molecular Physics

The process of the electron capture in energetic ion atom collisions has been an ongoing project. Different kinds of perturbation theories used to study this collision shows divergences. This arises because of the use of perturbation expansion in terms of plane wave basis. Such expansion is known to diverge at energies of the relevant bound states. We have avoided the use of expansion in terms of plane waves. In this new approach, the Born expansion is made in terms of the target and projectile Green functions. This is shown to be free of divergences at the energies of the bound states.

Nuclear Physics

This year a beginning is made in applying ideas based on symmetries to diversified problems in nuclear structure. Firstly a model for rotational bands built on quasi-particle excitations is introduced and it is based on good pseudo-spin symmetry and SU(3) symmetry for the quasi-particles and good SU(3) symmetry for the core nucleus. Secondly, analytical results for the so called group representation matrix elements are derived in the SU(3) symmetry limit of sdg interacting boson model and they are extended to the case of a general ground and 1-phonon excited bands. These expressions determine the cross-sections (in Eikonal approximation) for medium energy proton scattering off nuclei and also sub-barrier fusion cross-sections, when the target nucleus is deformed.

Foundation of Classical and Quantum Mechanics

The quantum behaviour of classically chaotic system still possess many features following from the classical dynamics. One such phenomena - namely localization of eigenfunctions in configuration space around the classical orbits was studied earlier. We have now looked at the information entropy for such system defined using the configuration space eigenfunctions. It was shown in the specific case of two coupled quartic oscillator that entropy for this system exhibits sharp minima in case of localized states.

MACROSCOPIC PHYSICS

Astrophysics

Accretion Disks in the Presence of Poloidal and Toroidal Magnetic Field

Earlier studies of equilibrium structure for accretion disks in the presence of radial gravitational field and poloidal magnetic fields have revealed several interesting features on the possible critical fields for having disks quite close to compact objects. As the plasma in the disk rotates around, it would generate poloidal currents that could give rise to toroidal magnetic field and it is necessary to consider the role of coexisting poloidal and toroidal magnetic field alongwith the gravitational fields. Having set up the required formalism in fluid approximation in the Newtonian theory for a disk around a gravitating compact object with a dipolar magnetic field, we have solved the system of magnetohydrodynamic equations for the case of disk fluid having only the azimuthal component of the velocity non-zero. The toroidal field goes as $r^{-5/2}$ and the currents as $r^{-7/2}$ whereas the density and pressure distributions go as r^{-4} and r^{-5} respectively. The toroidal field strength happens to be higher than the poloidal field strength which appears favourable for confining the plasma in equilibrium producing a thick structural disk around the central gravitating body. The analysis is being made using two different approaches (field and potential) looking for consistency of such equilibrium configuration. Further work in this direction would take up the case of non-zero radial velocity and stability under radial and azimuthal perturbation.

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

Dynamics of Rotating Ultra Compact Objects with the Centrifugal Force acting along the same Direction as Gravitation

We have shown earlier that in the context of ultra compact objects, the centrifugal force acting on a test particle reverses sign if the particle happens to be at a distance $r \leq 3MG/C^2$ and this has important role to play in the behaviour of ellipticity of the rotating fluid configuration like McClaurin spheroid. In order to understand the full dynamics of this, it was necessary to formally include the pressure gradient forces into the system of force equations. This has been now completed. Moreover, in the case of a purely stationary-axisymmetric configuration, the equation of hydrodynamic balance has been exactly solved for the adiabatic equation of state with a general polytropic index.

(A.R. Prasanna)

Critical Mass and Angular Momentum of Rotating Ultra Compact Configuration having Strange Matter

In the context of dynamics of rotating ultra compact objects, if the equilibrium exists with non-Keplerian configuration (pressure gradient balancing both gravitation and centrifugal), the kind of matter distribution inside could be way beyond nuclear densities. In this context we are investigating the possible critical limits that would arise for equations of state having T^7 dependence on temperature in the case of quark matter.

(A.R. Prasanna and S.B. Khadkikar)

Large Scale Structure

The aim of this study is the identification and classification of the large scale structures (clusters, voids etc.,) found observationally. This is a detailed 'microscopic' study of observational data that will complement statistical studies e.g., those based on correlation functions.

The technique is based on calculating the expectation (probability) of these structures given a random (binomial) background distribution of galaxies. To begin with, three parameters have been considered viz., the angular coordinates and the radial velocity. Neglecting proper motion and using Hubble's law, this provides the distance between each pair of galaxies. The expectation is calculated from this information.

In order to determine the appropriate ranges of the parameters (in this case, properly normalized values of the expectation, angular separation and difference in velocity) corresponding to various possibilities, a theoretical study of a 'model' distribution was undertaken. Various possibilities, such as physical connection, random distribution, voids and 'discordant' radial velocities have been considered.

The technique has been applied to the galaxies listed in the Harvard-Smithsonian Center for Astrophysics (CfA) catalogue. The catalogue contains over 40,000 sources, for over half of which velocities have been determined. Initially, a small section of the sky (corresponding to RA between -0.2 and 0.6 degrees) was studied. About 20 structures of different multiplicities have been identified. A detailed study of the characteristics of these structures is underway. One byproduct of this analysis is the identification of objects for which it would be of particular interest to observationally determine velocities.

The full CfA catalogue covering the whole sky is now being considered. It is also planned to consider other parameters like magnitude and morphological type.

(Sai Iyer)

Centrifugal-force Reversal in General Relativity

It is seen that when an appropriate 3+1 splitting and conformal transformation are availed of, the exact general- relativistic force acting on a particle in a stationary spacetime can be analysed in terms of concepts familiar in Newtonian mechanics, viz., gravitational, centrifugal and Coriolis forces.

A careful re-analysis has been performed of the reversal of centrifugal force in the Kerr spacetime, using locally non- rotating frames, which have been shown to be the appropriate frames in this case. This analysis has been employed to study the variation in the ellipticity of a slowly rotating Maclaurin spheroid and the existence of a maximum in the ellipticity. The phenomenon is now being studied in the case of the Hartle-Thorne metric which more accurately represents the spacetime outside a rotating object.

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

Energy and Momentum of Cylindrical Gravitational Waves

Using Einstein's energy-momentum pseudotensor we calculated energy and momentum densities of cylindrical gravitational waves (described by Einstein-Rosen solution) in "cartesian coordinates" and found them to be finite and reasonable. This work was done in collaboration with Prof. Nathan Rosen.

Recently we have calculated the same in prescriptions of Tolman and Landau and Lifshitz and have found that they give same result as obtained in Einstein's prescription.

(K. S. Virbhadra)

Gravitational Energy of a Stringy Charged Black Hole

It is known that a static, spherically symmetric stringy charged black hole has several different properties than that of the Reissner-Nordstrom black hole. We obtained the gravitational energy of the stringy charged black hole and found that the total energy is positive and is confined to the interior of the black hole. This is in contrast to the result for the Reissner- Nordstrom black hole, where the total gravitational energy is positive but is shared by its interior as well as exterior. Consequently, unlike the case of the Reisnner-Nordstrom black hole, the effective gravitational mass experienced by a neutral test particle situated at any finite distance in the gravitational field of the stringy charged black hole is positive.

(K. S. Virbhadra and J. C. Parikh)

A Conformal Scalar Dyon Black Hole Solution

It is known that the stress tensor of the conformal scalar equation is different from that of the ordinary massless scalar equation and it has several interesting properties. Inspired by these we obtained an exact solution of Einstein-Maxwell- Conformal scalar field eqaution, which is a black hole solution and has three parameters: scalar charge, electric charge, and magnetic charge. Switching off the magnetic charge parameter yields the solution given by Bekenstein. In addition we have obtained the total gravitational energy of the conformal scalar dyon (CSD) black hole. It is equal to the CSD charge of the black hole, where the CSD charge is defined to be square root of the sum of squares of scalar, electric, and magnetic charges. As the total gravitational energy of an isolated system is always positive, one can see that, as opposed to the electric or magnetic charges, only the positive conformal scalar charge is permissible.

(K. S. Virbhadra and J. C. Parikh)

Meteorology and Climate Studies

Climate Modelling Relevant to IGBP

Modelling global changes caused by natural and/or anthropogenic activities is a major component of the IGBP. In particular the study of variability of monsoon and tropical circulations on the interannual and longer timescales forms an important aspect of modelling global changes relevant to IGBP. An important topic of current research is understanding climate changes caused by deforestation. Two central requirements for these types of studies are (i) a high resolution coupled atmosphere-ocean model incorporating relevant physical processes of monsoon and global climate and (ii) adequate computational facility. During this year, we have begun work on the development of an atmosphere-ocean coupled model using the global atmospheric model earlier developed at PRL as a basis. The latter is a three dimensional spectral global model with horizontal resolution of ten waves and a vertical resolution of five levels and uses simple schemes for treatment of horizontal diffusion and latent heat release in cumulus clouds. It has no orography. It has been used successfully for several idealized studies of monsoon dynamics. It is proposed to improve the dynamics and convection schemes of this model. For a realistic treatment of cumulus convection the modified version of Kuo's cumulus parameterization scheme will be included. A reduced gravity ocean mixed layer model will be coupled to the atmospheric model. Progress made so far includes increasing the horizontal resolution of the model to 35 waves and incorporation of orography appropriate for this high resolution. Further work is in progress.

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

Further Studies in Dynamics of Monsoon Depressions

In the past we have studied several important aspects of dynamics of monsoon disturbances using both simple two-level and complex multi-

level global atmospheric models. Useful insights have been obtained by these studies into dynamical and physical mechanisms of formation of these disturbances and their energetics. During this year studies were continued with a view to understand the dynamics of trajectories of these disturbances. Observationally, monsoon depressions forming over north Bay of Bengal are seen to move west- northwest most often but sometimes they move to the north or northeast. To understand this behaviour, we started with a model generated monsoon type basic flow produced by applying an appropriate south to north heating gradient in the model. Next, vortices of different sizes were superposed on this basic flow in the region where the basic flow is expected to be unstable (21^{o}N latitude). A Charney-Eliasen type heating for cumulus heating was used and the model (35 wave, 5 level) was integrated for five days. Preliminary analysis of results shows that vortices amplify under the influence of cumulus heating and basic flow instability. The tracks of the moving disturbances are seen to be westnorthwest, north or northeast depending on the size of the vortex. Further work is in progress.

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

Plasma Physics

Nonlinear Evolution of Driven Chaotic Alfvén Waves

Large amplitude Alfvén waves as well as Alfvénic turbulence has been observed in a variety of space plasmas. Earlier (Phys. Fluids. B2, 2581, 1990; Jou. Geophys. Res., 97, 4229, 1992) we had shown that the localised stationary nonlinear Alfvén waves driven by an external source can become chaotic. Now with the help of Spect Code, we find that in the initial stages of nonlinear evolution, these driven waves are quasi-periodic but the indications are that at a later stage, when the driver is sufficiently strong, Alfvén waves do become chaotic. From the time series thus obtained, we determine the spectra. Calculations for correlation dimension and Liapunov exponents, which characterize the chaotic behaviour, are in progress.

(B. Buti)

Hysteresis in Nonlinear Alfvén Waves

Nonlinear Alfvén waves are governed by Vector Derivative Nonlinear Schrödinger equation. In the initial stages of their temporal evolution, our numerical analysis shows that the evolution is very sensitive to the initial conditions. The amplitude of the wave increases with the amplitude of the driver (A) initially slowly but for A=A there is a sharp jump. Now if we use this as the initial condition and slowly decrease A, we see that the wave amplitude, to start with, decreases slowly but at A=A , it shows a sharp decrease. This is like the phenomenon of hysteresis in magnetism.

(B. Buti)

Convective Cells in Nonuniform Dusty Plasmas

It is shown that purely damped convective cell modes acquire a real frequency in the presence of static charged dust grains in a nonuniform magnetized dusty plasma. The frequency of the two-dimensional mode is induced by the plasma density gradient and corresponds to charge density waves arising out of the plasma non-neutrality. The dynamics of weakly interacting finite-frequency convective cell modes is governed arising from the dust inhomogeneity in the latter which provides the possibility of a two-dimensional dipolar vortex solution in dusty plasmas.

This work was carried out in collaboration with P.K. Shukla of the Ruhr University, Bochum.

(R.K. Varma)

Alfvén Vortices in Nonuniform Dusty Magnetoplasmas

The Alfvén waves are shown to be linearly coupled with finite-frequency convective cell modes in a nonuniform cold dusty plasma.

The dynamics of weakly interacting finite-amplitude electromagneic oscillations is governed by a pair of nonlinear equations. The latter admit dipolar vortices as possible stationary solutions, where translatioal speed is well determined, but whose size is arbitrary. It is stressed that in the absence of charged dust grains, the formation of a dipolar Alfvén vortex is forbidden in the absence of parallel electron inertia in a cold plasma. The present results should be useful for understanding the linear and nonlinear properties of electromagnetic turbulence in dusty plasmas that often exist in cometary tails and interstellar clouds.

This work was carried out in collaboration with P.K. Shukla of Ruhr University, J.F. McKenzie of Max-Planck-Institut für Aeronomie and Vinod Krishan of the Indian Institute of Astrophysics.

(R.K. Varma)

Electrostatic Oscillations in the Presence of Grain Charge Perturbations in Dusty Plasmas

The properties of electrostatic oscillations and instability phenomena are studied, accounting for the time-dependent variation of the grain electric charge due to wave motions in an unmagnetized dusty plasma. It is found that charge fluctuations on the dust grains give rise to two purely damped modes, in addition to causing a collisionless damping of the existing normal modes.

It appears that a dusty plasma with the dust charge perturbation behaves like a dissipative system and the damping of the modes arises because of the phase difference between the total perturbed dust charge density and the wave potential. Furthermore, accounting for the dust charge perturbation, we have also established the existence of some interesting electrostatic instabilities for three cases, in which (i) the inertial charged dust fluid streams with respect to the Boltzmann - distributed electrons and ions, or (ii) the inertial electron fluid streams with respect to stationary ions and charged dust particulates. The instabilities are attributed to a linear coupling between a negative-energy wave and a resistive medium.

This work was carried out in collaboration with P.K. Shukla of Ruhr University, Bochum and Vinod Krishan of the Indian Institute of Astrophysics.

(R.K. Varma)

A Mechanism for Plasma Irregularities in Lower Ionospheric Plasma

A new mechanism for the generation of plasma irregularities in the ionospheric plasma particularly in the auroral region is proposed on the basis of an instability that arises due to presence of equilibrium density and temperature gradients in a weakly ionized magnetoplasma. The effects of both elastic and inelastic collisions are considered. The growth of the instability is found to depend on the charged particles' collision with neutrals and on the ratio between the density scale length L_N and that due to temperature gradient L_T, which is usually denoted by $\eta = (L_N/L_T)$. It is also seen to have cut off for higher wave length which, probably, is the consequence of inelastic collisions of electron with neutrals.

This mechanism is capable of producing irregularities with velocity larger than ion-acoustic velocity and may be important for some observed phenomena of auroral electrojet irregularities with unusual spectral signature that has been identified as type-4 spectrum of radar aurora. The existence of this instability is supported by the electron density and temperature gradients measured with EISCAT in the auroral region. This work is done in collaboration with A.G. Sheikh of C.U. Shah College, Ahmedabad

(A.C. Das)

New Type of Magnetoacoustic Wave in Dusty Plasmas

We report the existence of a qualitatively new kind of hydromagnetic wave in a three—component dusty plasma consisting of electrons, ions and charged dust particles. The new modes are electromagnetic in nature, and are accompanied by compressional magnetic field and number density perturbations. We call these modes "Dust—Magnetoacoustic Waves" in order to distinguish them from the usual type of magnetoacoustic waves in a three—component plasma. The dispersion relation for the dust-magnetoacoustic wave is qualitatively different from that for the usual magnetoacoustic wave, and is given by

$$\frac{\omega^2}{k^2} = \frac{1}{m}\left\{ \frac{Z\gamma_i T_i}{(n_{io}\gamma_e T_e + n_{eo}\gamma_i T_i)} \frac{B_o^2}{4\pi} \right.$$

$$\left. + \frac{Z^2 n_o \gamma_e T_e \gamma_e T_i}{(n_{io}\gamma_e T_e + n_{eo}\gamma_i T_i} + \gamma T \right\}$$

where Z, m, n_o, γ and T denote, respectively, the charge number, the particle mass, the equilibrium number density, the adiabatic index and the temperature corresponding to the dust component, and the remaining notations are standard. The dust-magnetoacoustic modes arise in a dusty plasma when because of the finite non-zero mass of the ions the ion dynamics is also included in the analysis. This results in an effective inertial resistivity which makes the ion and the electron fluids non-frozen to the magnetic field lines whereas the dust fluid continues to be frozen to the field lines. This is in contrast to the case of the usual type of magnetoacoustic waves where all the three fluids would be frozen to the magnetic field lines. In the limit of the magnetic field going to zero, the above dispersion relation yields exactly the dispersion relation for the so -called "dust -acoustic waves" which we reported last year. Thus, the new modes are the electromagnetic generalization of the dust—acoustic waves obtained by relaxing the frozen-in-field approximation for the ion and the electron fluids. It is found that there are no counterparts of the new modes for the Alfvén waves since the latter do not involve any density perturbations.

(N. N. Rao)

Hydromagnetic Shocks in Magnetized Dusty Plasmas

We have developed a nonlinear model for describing low - frequency hydromagnetic shocks in magnetized dusty plasmas. In particular, we have analyzed in detail the existence as well as the structure of magnetoacoustic wave-plateau shocks driven by a suitable high-frequency driver mode such as an upper-hybrid wave or an O -mode electromagnetic wave. In either case, the shock front separates the plasma into two regions: An inner region having compressional density shelf with sub -magnetoacoustic flow speeds, and an outer region having rarefaction standing waves with super- magnetoacoustic flow. Thus, there exists a transition in the dust fluid flow speed from sub -magnetoacoustic to super - magnetoacoustic values via the shock front region. While it is possible in the small amplitude limit to analytically obtain the detailed structure of the shock region, numerical methods need to be used for large amplitude shocks. The flow velocity transition as well as the profile structure in the evanescent region obtained in our model have close similarities to those seen by Motschmann et al. [Geophys. Res. Letts., **19,** 225 (1992)] in their numerical simulations on the interaction of a streaming quasi—neutral magnetized plasma with a stationary charged dust cloud which acts like an obstacle for the plasma flow.

(N.N. Rao)

Kelvin—Helmholtz Instability Driven by Sheared Dust Flow

Stability analysis of the dust—acoustic mode in a magnetized three—component dusty

plasma having sheared flow in the dusty fluid has been carried out. Normalized critical shears required to excite the instability are found to increase for both positively and negatively charged dust as the ratio of the equilibrium charge density of the dust to that of the ions increases. The instability occurs when the relative velocity between the adjacent layers of the dust fluid becomes of the order of the dust—acoustic phase velocity which is qualitatively different from the usual ion—acoustic phase velocity. Relevance of this instability to the cometary plasma environment where the cometary dust particles flow through the solar wind plasma is pointed out. This work has been carried out in collaboration with S.P.S. Rawat.

(N.N. Rao)

MICROSCOPIC PHYSICS

Atomic and Molecular Physics

Electron Capture

Electron capture in energetic ion-atom collision is a fundamental atomic process of practical importance. For the past some years, we have been investigating high-energy electron capture and have already reported some important results. Now we are addressing some fundamental problems of capture theory. Although convergence properties of various Born expansions have been investigated by several authors over the years, they are not yet understood. It is well known that the Born expansion of the total Green's function for rearrangement collisions, obtained by using the free Green's function, has pathological behaviour causing it to diverge. This divergence arises from the bound state poles of the total two-body Green's function. Similar results have also been shown to hold for distorted wave Born series obtained by using the distorting potentials that do not lead to rearrangement processes. There are also some studies of the convergence property of the Born series based on the initial (or target) Green's function as well as the final (or projectile) Green's function. These studies have claimed that these Born expansions also diverge for the same reason, namely, due to the bound state poles of the related two-body Green's functions. However, these convergence studies have been performed by making further perturbation expansions (or the Born expansions) of the target and projectile Green's functions in terms of the free Green's function. To us, this process of representing the target or projectile Green's function by the Born expansion in terms of the free Green's function does not seem to be a theoretically sound method. This is because a perturbation expansion of a quantum mechanical bound state problem on plane wave basis diverges at the energies of bound states. Therefore, we have re- examined the problem by a method which completely avoids the use of the free Green's functions and the associated plane wave states. We have been able to demonstrate that the Born expansions in terms of the target and projectile Green's functions do not show the pathological behaviour arising from the bound state poles of the two-body Green's function which is encountered in the Born series in terms of the free Green's function.

(D.P. Dewangan)

Collisions of Charged Particles with Hydrogen-like Ions

Excitation of hydrogen-like ions in their excited states by the impact of electrons occur in a wide variety of astrophysical objects and therefore rate coefficients for these inelastic processes are important in astrophysical context. For the past 2-3 years, we have been investigating excited-state to excited state transitions of hydrogen-like ions and have already reported a new one-dimensional integral representation of the

Coulomb-modified Glauber amplitude for arbitrary nlm → n'l'm' transitions. Using this one-dimensional integral, we are calculating cross sections and rate coefficients for excited-state to excited-state transitions of HcII and CVI ions by electron-impact.

(D.P. Dewangan)

Classical and Quantum Mechanics

The Generalized Schrödinger Formalism as an Amplitude Representation of the Generalized Liouville Equation of Classical Mechanics

We have obtained an amplitude representation of the generalized Liouville equation of classical mechanics which uses, besides the standard 2N positions and momenta, also the action $S = \int L\, dt$ as an additional phase space coordinate (so that one has a (2N + 1) dimensional phase space)

It is found that this generalized amplitude representation is precisely the generalized Schrödinger set of equations obtained by theauthor earlier using a generalization of classical mechanics to include an angular coordinate to enhance the dimensionality of the configuration space. The importance of this derivation lies in the fact that the starting point is nothing more than the classical mechanical formalism. The Schrödinger formalism (generalized) simply turns out to be the amplitude representation of the latter. This may appear intriguing, but a recent experimental demonstration of the existence of discrete 'forbidden' and 'allowed' energy states of a (certain) classical mechanical system may provide a case in favour of the above finding.

(R.K. Varma)

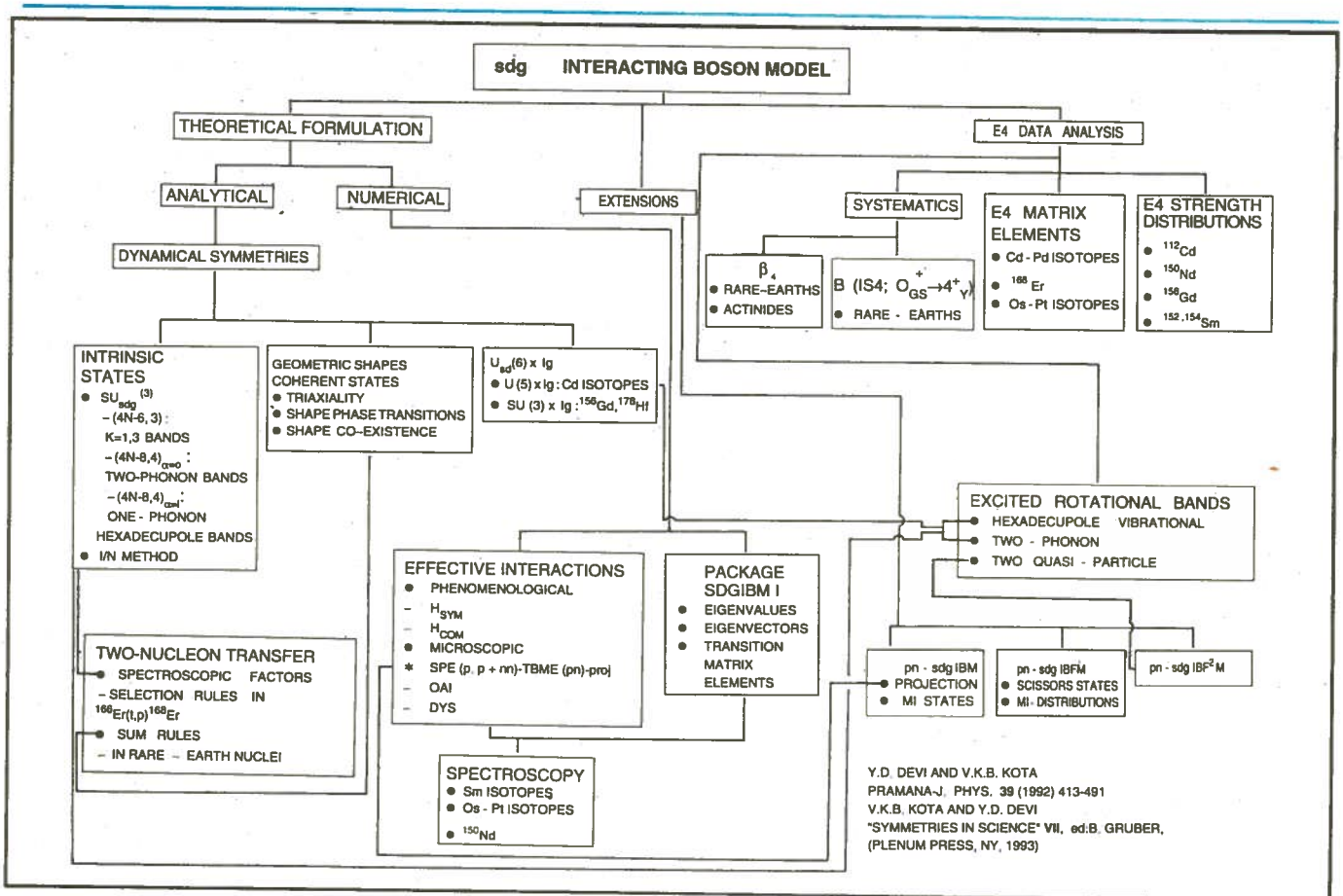
Local Realism and Bell's Inequalities

In the framework of local hidden variables, a definition of correlation function (CF) is introduced for the measurement of spin components in the Bohm gedanken experiment, which is different from the definition given by Bell. Though different in form, this expression for the CF is nevertheless consistent with Einstein locality and is in the spirit of the structure of the EPR argument. The correlation function so introduced has been shown here to return the quantum mechanical expectation value for the results of measurement on the two spins. It, therefore, appears that Bell's definition of locality is a little too restrictive to allow for a definition of correlation function used herein. It is, therefore, not the locality, but Bell's specification thereof which may be responsible for the known incompatibility between Bell's inequalities and quantum mechanical predictions.

(R.K. Varma)

Application of Time Dependent Perturbation Theory to the Henon-Heiles Hamiltonian

We had shown earlier that the singularities of Canonical Perturbation Theory can be removed by considering Time dependent Perturbation Theory. We have now tested this theory by applying it to the Henon-Heiles Hamiltonian. Results show that the third order gives very good agreement with exact (numerical) computations for low energies. As the energy approaches E =1/6, the agreement becomes very poor. We have argued that this could be due either to the occurrence of chaos in the Henon- Heiles Hamiltonian or the occurrence of unbounded orbits beyond E = 1/6. To decide between these cases, we have applied the theory to the case of the anti-Henon-Heiles, which is integrable (non-chaotic), but does show similar unbounded orbits beyond a critical energy. We have also applied the theory to two orbits, one chaotic and the other regular, at the same energy for the Henon-Heiles system. Our results show that the disagreement appears to be more due to the unbounded orbits than due to chaos. Further applications, to other Hamiltonian systems which



*4.1 Schematic overview of various developments in sdg IBM and its applications in analyzing data on hexadecupole observables (details are given in the review article by Y.D.Devi and V.K.B. Kota; Pramana - J. Phys. **39** (1992) 413)*

show chaos but do not have unbounded orbits, are in progress.

(Mitaxi Mehta and B.R. Sitaram)

Classical and Quantum Structures in a Two-Dimensional Quartic Oscillator

In our previous work on chaotic quantum systems we have found that some of the quantum eigenfunction are localized in configuration space. The scarring of eigenfunctions of chaotic systems by unstable periodic classical orbits is now well known but the localization phenomena is much less well studied. We are investigating structures in the classical periodic orbits and in the quantum eigenstates and their interrelationship. This work is being done in collaboration with J. Gao and J.B. Delos

(V.B.Sheorey)

Information Theory and Chaotic Quantum States

We have shown that an information entropy measure based on the configuration space eigenfunctions for a two dimensional quantum system consisting of two coupled quartic oscillators exhibits sharp minima for localized states. These results have been verified by the direct visualization of the quantum density. We have also found a similar result in the conjugate space, i.e., the momentum space. The visualization of momentum space densities, however, does not appear to exhibit localization and further work is being done. Our method appears to be useful for identifying localized eigenstates in multidimensional systems. The nature of these entropies need to be further investigated with a view of study-

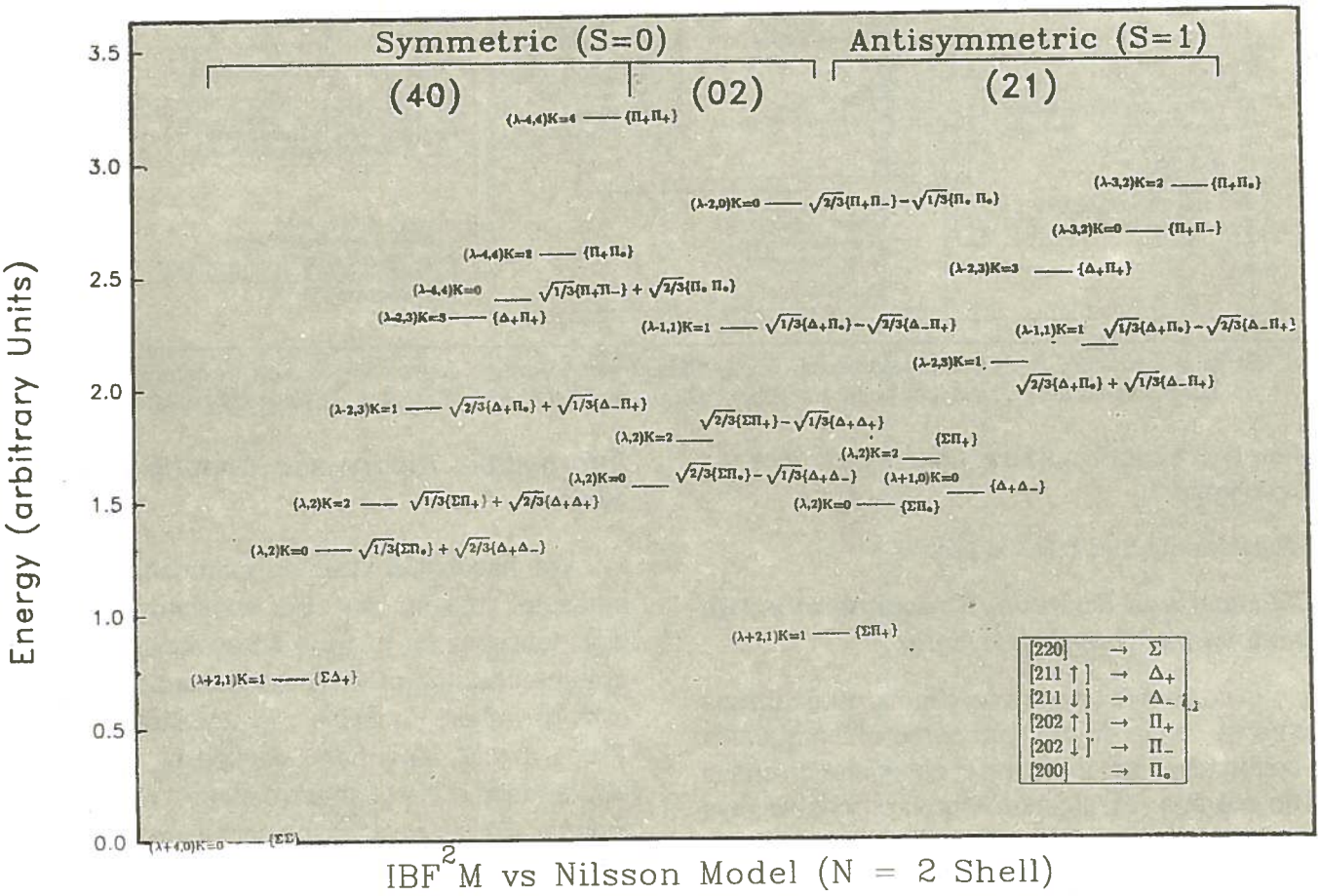
ing the imprint of classical chaotic dynamics in them.

(V.B.Sheorey)

Nuclear Physics

sdg Interacting Boson Model - Overview

In the last eight years we worked out the complete formulation of the sdg interacting boson model. Both analytical and numerical aspects of the model are developed by deriving large number of analytical formulas for various observables by employing dynamical symmetries and coherent states and by developing the package SDGIBM1 which enables one to perform systematic calculations in sdg space for various spectroscopic properties of nuclei. The sdg model is successfully applied in the analysis of data on various quadrupole and hexadecupole observables. This



4.2 The classification of two quasi-particle states in Nilsson Model (labelled [$Nn_z\Lambda$] [$Nn_z'\Lambda'$) and in the SU(3) ⊗ U(2) limit of IBF^{2}M model (labelled ($\lambda\mu$) k) for the N = 2 oscillator shell. In the figure $\lambda = 2\bar{N}$ and $4\bar{N}$ for sd and sdg models respectively; $\bar{N}$ being the boson number

project culminated in two review articles written by us. One of them deals exclusively with the symmetry aspects of the model and the other highlights the analysis of data on hexadecupole observables. The schematic summary of this project, which ended this year, is shown in the fig. 4.1.

(V.K.B. Kota and Y.D. Devi)

Two Quasi-particle Excitations in the SU(3) x U(2) Limit of IBF2M

The study of high spin states in the framework of Interacting Boson Model (IBM) involves coupling of two (and higher) quasi-particle (qp) excitations to the core described by the (2N,0) irrep of the SU(3) limit of IBM; N is boson number. When the qp's occupy natural parity orbits (which seems to be the case with many low-lying two qp bands appearing ~ 2 MeV excitation and more importantly the super-deformed (SD) bands) and pseudo-spin is a good quantum number, the pseudo- SU(3) description of the qp's can be coupled to the core (2N,0) irrep. The resulting coupling scheme for two qp's is the SU(3) x U(2) limit of Interacting Boson Two-Fermion Model (IBF2M). Using the large-N limit expressions for the SU(3) $\supset$ O(3) Wigner coefficients (in spherical basis) or equivalently the SU(3) $\supset$ [SU(2) $\supset$ U(1)] x U(1) Wigner coefficients (in the intrinsic basis) the exact correspondence between the SU(3) irreps of IBF2M and the two qp Nilsson configurations is established (results for N=2 shell are shown in the figure 4.2). With this one has a realistic model to deal with two (multi!) qp excitations where the structure of ground, beta and gamma bands is kept intact and the structure of qp excitations is asymptotically identical to the Nilsson Model (which is not the case with the pseudo-SU(3) description of all the valence nucleons). An additional feature of this model is that qp excitations are dealt with in the laboratory frame. Work related to derivation of analytical expressions for various observables in the SU(3) x U(2) limit of IBF2M is in progress.

(V.K.B. Kota and Y.D. Devi)

Partition Functions in the Dynamical Symmetry Limits of the Interacting Boson Model

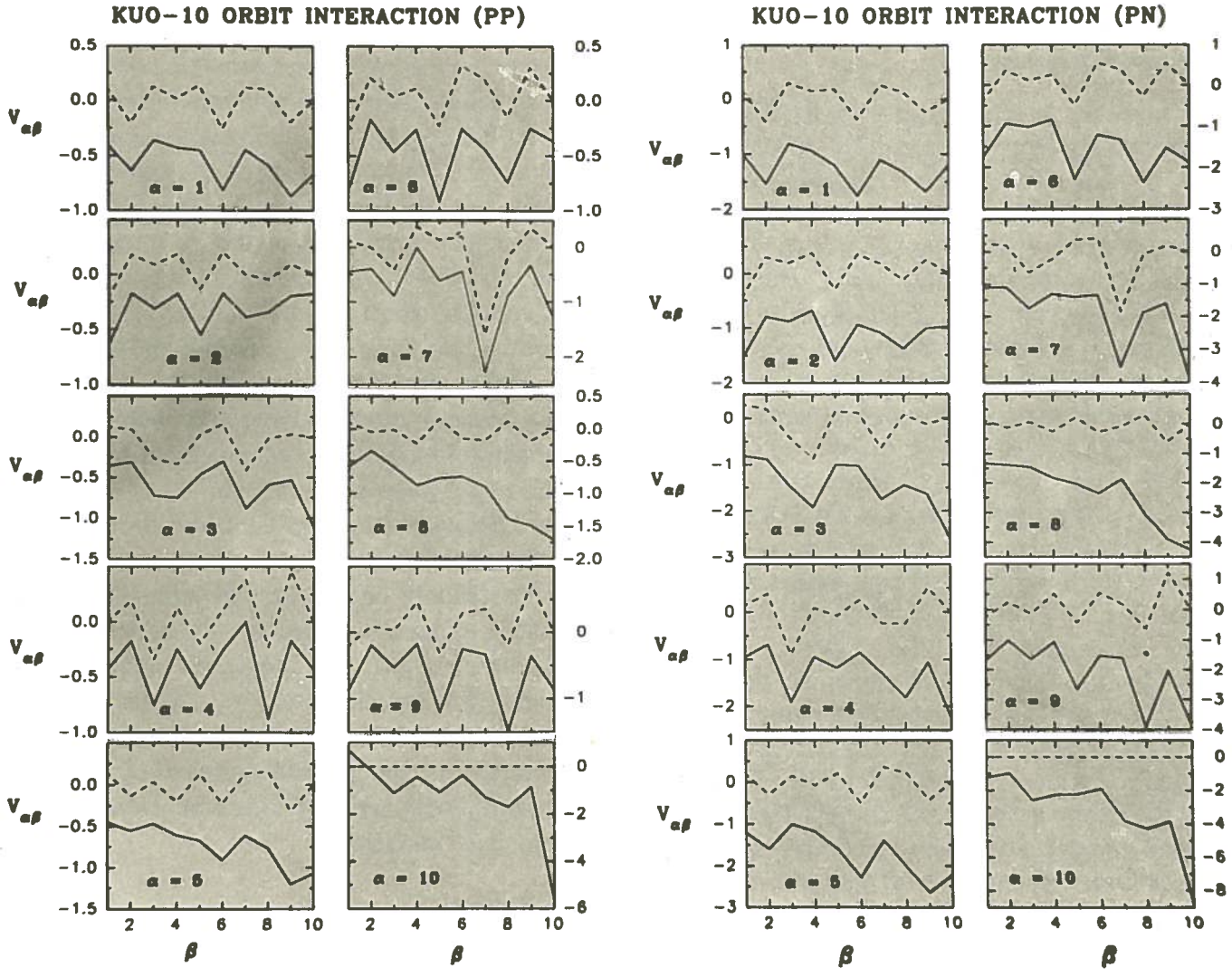
In the large boson number (N) limit, analytical formulas for the partition functions (Z) are derived in the three dynamical symmetry limits (U(5), SU(3), and O(6)) of the interacting boson model (IBM). In the vibrational U(5) limit the partition function is that of five dimensional oscillator and in the rotational SU(3) limit it decomposes into rotational (square of spin cut-off factor (σ^2) and vibrational (that of a three dimensional oscillator) parts. These are essentially same as the geometric model results due to Bjornholm, Bohr and Mottelson and Ignatyuk (thus our results disprove the recent claim of Maino, Mengoni and Ventura who state: Z_{coll} (β) in IBM cannot be written in the form of a product of vibrational and rotational partition functions Z_{vib} Z_{rot} as is usually done in the traditional approaches to the calculation of collective enhancement factor). In addition IBM gives an expression for O(6) nuclei; in the gamma - unstable O(6) limit the partition function decomposes into O(6) (one dimensional oscillator) and O(5) (gamma - unstable vibration) parts. Finite boson number effects are studied numerically and they are found to be important for temperatures T > 1 MeV. These results make it plausible that for T $\leq$ 3 MeV one can use IBM in place of the geometric model for estimating collective enhancement factors in nuclear level densities.

(V.K.B. Kota)

Eikonal Scattering in the sdg Interacting Boson Model

General expression for the group representation matrix elements (GRME) in the $SU_{sdg}(3)$ limit of the sdg interacting boson model (sdgIBM) is derived that determine the scattering amplitude in the eikonal approximation for medium energy proton-nucleus scattering when

the target nucleus is deformed and it is described by the $SU_{sdg}(3)$ limit. The $SU_{sdg}(3)$ result is generalized to two important situations : (i) when the target nucleus ground band states are described as states arising out of angular momentum projection from a general single $K^{\Pi} = 0^{+}$ intrinsic state in sdg space; (ii) for rotational bands built on one-phonon excitations in sdgIBM. The



4.3 Average two particle energy $V_{\alpha\beta}$ that defines the spherical configuration scalar part of a nuclear interaction for various ($\propto$,β) values. The continuous curve is for the Kuo - 10 orbit interaction defined in nuclear (s,p,sd,fp) space (the interaction is due to T.T.Kuo) and the dashed curve is for the unitary two-body part of Kuo - 10 orbit interaction; results for proton-proton and proton-neutron parts of the interactions are shown in the figures. It is clearly seen that the unitary two-body part which is obtained by subtracting the unitary 0 and 1 - body parts from the interaction fluctuates around zero and these fluctuations are ignored in the level density theory. In the figure $\propto$ (β)= 1,2,3 ... 10 correspond to $^{1}S_{1/2}$, $^{1}P_{3/2}$, $^{1}P_{1/2}$, $^{1}d_{5/2}$, $^{1}d_{3/2}$, $^{2}S_{1/2}$, $^{1}f_{7/2}$, $^{1}f_{5/2}$, $^{2}p_{3/2}$ and $^{2}p_{1/2}$ respectively

GRME and their extensions that we derived also determine the sub-barrier fusion cross-sections (where all channels couplings are taken into account by employing the path integral formalism in IBM developed by Balantekin and Takigawa) when one of the nuclei is deformed (as in ^{16} O + ^{154}Sm example). Here the relevance of sdg IBM stems from the fact that there is good experimental evidence for the importance of hexadecupole deformation in sub-barrier fusion. Analysis of data using our expressions for GRME is in progress.

(V.K.B. Kota)

Unitary Decomposition of Spherical Configuration Scalar part of Nuclear Hamiltonians all across the Periodic Table

Unitary decomposition of the spherical configuration scalar part of various nuclear hamiltonians (the average two particle energy $V_{\alpha\beta}$ produced by the interaction with a particle in the spherical orbit α and the other in the orbit β defines the spherical configuration scalar part of the interaction $V_{\alpha\beta}$) in different parts of the periodic table is carried out. This exercise is one of the most important parts of the recently proposed theory for nuclear level densities with interactions. It is found that the unitary one- body part (which behaves effectively as a non-interacting particle (NIP) hamiltonian) of the interaction that renormalizes the single particle energies is highly correlated with the primary energies. The unitary two-body part that produces renormalizations which are not representable by NIP hamiltonian gives ~ 2% correction to the norm of the total hamiltonian and hence it can be neglected (figure shows that the two-particle matrix elements $V_{\alpha\beta}$ of the effective two-body part fluctuates around zero). These results are shown to be valid for almost all interactions and independent of the region of the periodic table.

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

Particle and Fields

Constraining the Weak Gyromagnetic Ratio of the W Boson in Future Single-Z Production Experiments

The charged W boson which mediates weak interactions, is predicted to have a gyromagnetic ratio g_w 1 in a local gauge theory. However, this has yet to be verified by direct measurement, and this would be done at the LEP200 accelerator at CERN, Geneva, in the near future by studying the processes $e^+ e^- \rightarrow W^+ W^-$. In analogy with the magnetic moment, which has to do with the electromagnetic interactions, one can define a "weak" magnetic moment, which occurs in the interaction of a particle with the heavy Z boson. The consequent "weak" gyromagnetic ratio (g_w) of the W is also predicted to be 1 in a local gauge theory. The weak gyromagnetic ratio cannot be measured separately in $e^+ e^- \rightarrow W^+W^-$. This work proposes $e^+ e^- \rightarrow Z \nu\bar{\nu}$ as a process where g_w may be measured. Analytic expressions for Z distributions in the process have been obtained Numerical estimates of the accuracy of measurement of g_w for different electron beam energies and luminosities are currently being determined. This work is done in collaboration with Dr. J.P. Singh of Jiwaji University, Gwalior.

(S.D. Rindani)

Higgs Boson and Majoron Model

In many extensions of the standard SU(2) x U(1) model, the conventional Higgs field tend to decay mainly into a pair of massless Goldstone bosons called majoron. In these models the decay of Higgs into quark antiquark pair is suppressed and it could happen that the Higgs may be missed experimentally even if it is produced. The implications of the LEP data for bounds on the mass of such a Higgs are worked out.

(A.S.Joshipura and S.D. Rindani)

Models for Neutrino Masses and Invisibly Decaying Higgs

Many of the models for neutrino masses contain a massless Goldstone boson. The Higgs boson in these models could decay into invisible channel. This possibility is investigated in a wide variety of models for the neutrino masses. It is concluded that Higgs mainly decays to invisible channel in models of neutrino masses which are characterized by the spontaneously broken lepton number at or below the weak scale. Many models with this feature are identified. This work is done in collaboration with J.W.F. Valle.

(A.S.Joshipura)

Models for 17 keV Neutrino

There has been a lot of interest in neutrino physics in recent times with the belief that it will give us some indication to the physics beyond the standard model. One of the recent findings of 1 % admixture of a 17 keV neutrino with the electron neutrino requires certain types of extension of the standard model. We proposed a simple variation of the Zee-type model including a U(1) global symmetry which can accomodate this new finding. The 17 keV neutrino decays fast enough through singlet Majoron at the one loop level to the massless elctron neutrino in this model. All astrophysical, cosmological and laboratory constraints are satisfied in this model. Although the model is the simplest one to accomodate a 17 keV neutrino, it fails to explain the solar neutrino problem simultaneously. Another model has been proposed that not only produces the required hierarchy for the neutrino masses consistent with the mixing and decay constraints, but can also naturally account for a substantial (transition) magnetic moment for the nearly massless electron neutrino thus explaining the solar neutrino problem and the reported anticorrelation of the solar neutrino flux with the sunspot activity.Large magnetic moment for the near massless neutrinos is generated in this model using a mechanism proposed earlier by us,in which the magnetic moment term is generated only on breaking the symmetry unlike othermechanism thus allowing us to choose all the three fermion generations in the same footings under the symmetry. This work was done in collaboration with D. Choudhury.

(U. Sarkar)

Low Energy Constraints on Grand Unified Theories

Grand Unified Theories (GUTs) offer the possibility of a simple, but unified description of strong and electroweak interactions. The unified groups do not only breakdown to SU(3)X SU(2)X U(1) 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) X SU(2) symmetry. We show that the stringent bounds placed on $\sin^2\theta_W$ from a recent analysis of measurements at Large Electron Positron collider rule out any possibility of the survival of left-right symmetry at low energies in grand unified theories. Another interesting paradigm of the grand unified theories is the low energy unification scheme based on SU(15). We studied the supersymmetric version of this scheme in the light of the LEP data. We find that the nice feature of low energy unification is lost in the supersymmetric framework, implying that any signal of supersymmetry will rule out the possibility of low energy unification and vice versa. We therefore calculated the left-right asymmetry parameters A , B and C in the polarised eD and ep scattering processes for two recently proposed un-unified models, which are the remnant extensions of the standard model of the low energy unification paradigm. Signatures of these un-unified groups would rule out any possibility of supersymmetry. We point out these experiments can not distinguish these models

from the standard model in the near future. This work was done in collaboration with K. Sridhar

(U. Sarkar and B. Brahmachri)

$q\bar{q}$ Pair Production in Non-Abelian Gauge Fields

$q\bar{q}$ pair creation probability in colour flux tube model including effects of non-abelian interactions in the theory has been determined. It is suggested that the colour field should be time dependent due to non-abelian interactions and hence should oscillate with a characteristic collective frequency ω_0 which depends on the field strength. The results show that in p-p and A-A collisions, either the perturbative estimate ($\omega_0 >> m$) or multigluon ionisation ($\omega_0 << m$) process often gives the dominant contribution, to the creation of $q\bar{q}$ pairs. This work was done in collaboration with P.K. Kaw of IPR.

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

Mass Spectrum in SO(10) Supergravity Model

An investigation of the mass spectrum of supersymmetric partners within the framework of a grand-unified supergravity model was carried out. Detailed predictions within such a framework, constrained by the requirement that tan β, a crucial parameter of the minimal supersymmetric standard model saturates its upper bound, as motivated by SO(10) unification were completed. This required the integration of a system of over twenty coupled renormalization group equations for all the parameters of the theory from the unification scale to the weak scale with boundary conditions so chosen as to meet all conditions of consistency placed by the choice of the vacua. Such a systematic study motivated by the successful "prediction" of a top-quark mass of $\geq$ 125 GeV now completes the predictions for the Higgs spectrum and dark matter candidates as well. This work is done in collaboration with G. Lazarides and Q. Shafi.

(B. Ananthanarayanan)

Two Vacua Random Phase Approximation (TVRPA)

A new formulation for proton-neutron random phase approximation for the purpose of calculation of the intermediate odd-odd nuclear states in double beta decay is given. The parent and daughter nuclear ground states in the double beta decay are treated as left and right vacua for the neutron annihilation-proton creation and its time reversal conjugate operator. In this way the number particle conservation is also taken into account by sandwitching the proper projection operator. The intermediate nuclear states and its energies are given uniquely in this formalism unlike the usual formalism which gives different states coming from right and left nuclei. Preliminary results for Se nucleus are obtained. Further calculations are in progress. These calculations are done in collaboration with G. Tenera, A. Faessler and F. Simkovitch. Double beta decay calculations with these states are planned.

(S.B. Khadkikar)

Meson Spectroscopy with COGEP

We have investigated the effect of exchange of confined gluons on the masses of light non-strange mesons in the frame work of relativistic harmonic model. The earlier phenomenological quark models put forth to explain the baryon and meson spectroscopy have incorporated the confinement of quarks, but the effect of confinement of gluons has not been taken into account. The essential new ingredient in our work is the investigation and analysis the consequence on the mesonic states taking into account of the confinement of gluons in addition to the conventional confinement of quarks.

For the confinement of quarks we are making use of the relativistic harmonic model (RHM) with Lorentz scalar+vector confinement potential. For

the confinement of gluons we have made use of the current confinement model (CCM) developed in the spirit of RHM. The confined gluon propagators (CGP) are derived in CCM. Making use of CGP we have obtained confined-one-gluon-exchange potential (COGEP) between the quarks. The COGEP has been successfully employed in nucleon- nucleon (N-N) scattering. Hence it is important to study its effect on mesonic and baryonic spectra. The pion is especially important as its observed mass (~ 137 MeV) is quite low compared to the naive mass of 400 MeV obtained by using COGEP perturbatively. It is expected that since the short range part of COGEP is attractive perturbative theory is not adequate.

So, in our present study of light meson spectroscopy the product of the quark-antiquark oscillator wave functions are expressed in terms of the oscillator wave functions corresponding to the relative and center-of-mass (CM) coordinates using the Moshinsky transformation. We have restricted the CM wave function to the Os state. The total energy or the mass of the meson is obtained by calculating the energy eigenvalue of the hamiltonian in the basis of harmonic oscillator wave functions. This is accomplished by forming a matrix of the hamiltonian operator and diagonalizing the matrix.

We obtained mass of the π and ρ mesons to be 188.37 and 687.037 MeV with $N_{MAX} = 5$ (where N corresponds to the oscillator quanta). The color-magnetic terms arising out of the confinement of gluons contribute significantly to the masses. We plan to construct the hamiltonian in a larger harmonic-oscillator- basis and diagonalize the hamiltonian matrix and extend it to study the heavy quark mesons also.

(K.B. Vijaya Kumar, A.K. Rath and S.B. Khadkikar)

List of Papers Published during 1992-93

Macroscopic Physics

Astrophysics

1. Sai Iyer and A.R. Prasanna, "Centrifugal force in Kerr geometry", Class & Quan. Gravity, **10** L13 (1993).
2. S.C. Tripathy, C.B. Dwivedi, A.C. Das and A.R. Prasanna, "Plasma instability at the inner edge of the accretion disk I", J. Astrophy. and Astron., 14 103 (1993).
3. Nathan Rosen and K. S. Virbhadra, "Energy and momentum of cylindrical gravitational waves", Gen. Rel. Gravit. **26**, 429 (1993).
4. K. S. Virbhadra,, "Gravitational field of a tachyon in a de Sitter Universe", Pramana, J. Phys., **40**, 273 (1993).

Meteorology and Climate Studies

1. Krishnakumar,V., R.N. Keshavamurty and Kasture, S.V., Moist baroclinic instability and the growth of monsoon depressions - Linear and nonlinear studies, Proc. Indian Acad. Sci. (Earth and Planet. Sci.), **101**, 123 (1992).
2. Krishnakumar, V., S.V. Kasture and R.N. Keshavamurty, "Linear and Nonlinear studies of the Summer Monsoon Onset Vortex", J. Meteor. Soc. Japan, **71**, 1 (1993).

Plasma Physics

1. B. Buti, "Chaotic Alfven waves in Multi-species Plasmas", J. Geophys. Res., **97**, 4229 (1992).
2. Das, A. C. and W.-H.Ip, "Particle Acceleration by Kinetic Alfve'n Waves in the Io Plasma Torus", Planet. Space Sci. **40**, 1499, (1992).
3. Das, A.C., "Lower Hybrid Turbulence and Tearing Mode Instability in Magnetospheric Plasma", J. Geophys. Res., **97**, 12275, (1992).
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1. D.P. Dewangan and J. Eichler, "The Z-expansion Method and Coulomb Boundary Conditions", Comments Atom. Mol. Phys., **27**, 317 (1992).

Classical and Quantum Mechanics

1. B. Ananthanarayan, G. Lazarides and Q. Shafi, "Radiative Electroweak Breaking and Sparticle Spectrum with tan a w mt/mb",Physics Letters, B300, 245 (1993).

Nuclear Physics

1. Devi, Y.D. and Kota, V.K.B., "Spectroscopy of Sm Isotopes in the sdg Interacting Boson Model", Phys. Rev. C45, 2238 (1992).
2. Devi, Y.D. and Kota, V.K.B., "Scissors States with and without g-bosons in the Interacting Boson-Fermion Model for Even-Odd Nuclei in N=82-126 Shell", Nucl. Phys., **A541**, 173 (1992).
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4. Devi, Y.D. and Kota, V.K.B., "M1 distributions in p-n sdgIBFM for odd-A Nuclei", Phys. Lett., **B287**, 9 (1992).
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8. Sarangi, S. and Parikh, J.C., "Dynamic microscopic basis for IBM-2 : A new approach" , Pramana, **40**, 43 (1993).

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1. Joshipura, A.S. and Rindani, S.D., "Width effects of the Z resonance and CP-violating asymmetry in $e^+ e^-$ annihilation", Pramana - J.Phys. **38**, 469 (1992).
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4. Joshipura, A.S. and Rindani, S.D., "Majoron models and the Higgs search,", Phys. Rev. Lett., **69**, 3269 (1992).
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6. D. Choudhury and Utpal Sarkar, "Neutrino Magnetic Moment and the 17 KeV ν_τ, Phys. Rev. Lett., **68**, 2875 (1992).
7. K. Bandyopadhyay, D. Bhowmick, A.K. Ray and Utpal Sarkar, "Distinguishability of some un-unified models," Phys. Rev., **D46**, 914 (1992) .
8. B. Brahmachari, K. Sridhar and Utpal Sarkar,"Ruling out low energy left-right symmetry in unified theories", Phys. Lett. **297B**, 105 (1992).
9. Utpal Sarkar, "17 KeV neutrino in a Zee-type model", Phys. Rev., **D47**, 1114 (1993).
10. B. Brahmachari and Utpal Sarkar, "Implications of Supersymmetric SU(15) Grand Unification", Phys. Lett. **303B**, 260 (1993).
11. P.C. Vinodkumar, K.B. Vijaykumar and S.B. Khadkikar, "Effect of the confined gluons in quark-quark interaction", Pramana - J. Phys. **39**, 47 (1992).
12. S.B. Khadkikar, J.C. Parikh and P.C. Vinodkumar, "Equation of State for Quark Gluon Plasma in a Relativistic Confinement Model", Modern Physics Letters, **A8**, 749 (1993).
13. Parikh, J.C. Quark-Gluon Plasma Collective Dynamics in "Medium and High Energy Nuclear Physics", Editors: M.K. Pal et.al., World Scientific (Singapore), 56 (1992).

Computer Centre

The Computer Center has the versatile DEC-1091 computer system. The main frame has a storage capacity of 512K words of 36 bits word length. Five disk drives are attached to the system. Four megnetic tape drive units of nine track are also attached to the system. 48 terminals including four with graphic display, out of which two with hard copy facility, two line printers and one card reader are attached to the system. The full configuration is supported by the time sharing TOPS-10 Operating System.

The centre has also two work stations DN 3500 and NEXUS 3000. Both the systems are connected with TOKEN ring network. They are attached with colour display monitor with key board and mouse. They are attached to NEC P5-X2 printer. The centre also has a PC/AT (BUSY BEE OF HCL).

The main activities of the centre are research and development in computer related areas of numerical methods, statistics, operations research, neural networks and library science besides consultation to the users.

A process is on to replace the existing mainframe system DEC - 1091 by a network of computers which may include a mainframe, saveral high-end and low-end work stations and a fairly large number of PCs. During the first phase it has been proposed to obtain three high-end workstations with LINPACK rating (100x100, DP) of about 40 mflops alongwith low-end workstations and PCs. In the second phase a powerful mainframe computer system will be added. The three high - end workstations will be on the fast FDDI network and other systems will be connected to a standard Earthernet network. One of the high-end workstations will act as a gateway between these two networks. With proposed new network configuration, PRL computer users would enter into the era of distributed and parallel computing in the UNIX environment. Besides the well-known mathematical packages such as IMSL, Mathematica etc. a powerful visualization package will also be available on the network to be accessed by many users simultaneously.

List of papers published in 1992-93

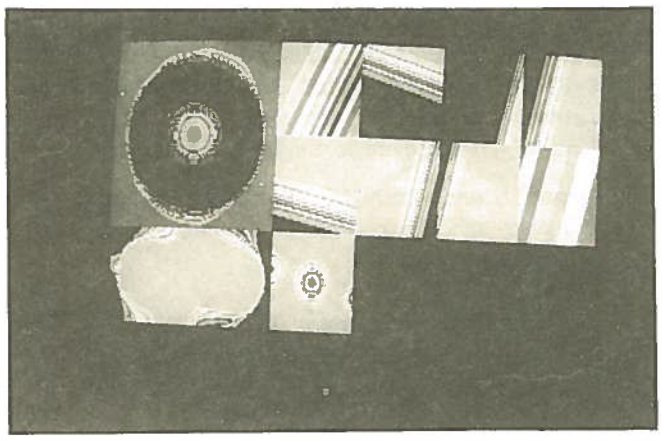
1. C.S.R.Murty,"Neural Networks as a tool for segmentd systems Modelling" ,Indian Computing Series; Innovative Applications in Computing Proc. ICC 1992, Tata McGraw Hill Publishing Co., New Delhi, 173 (1992).

Electronics Laboratory

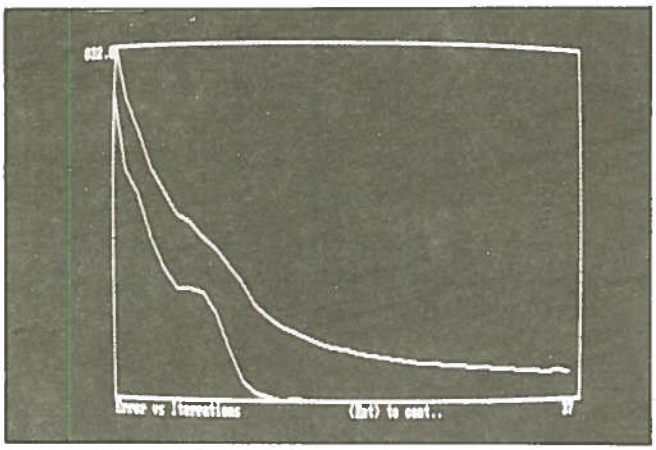
The Electronics Laboratory has started studies in the area of hardware and software of artificial neural networks for the last two years, alongwith specialized scientific instrument like "Ion Cyclotron Resonance Fourier Transform Mass Spectrometer"(ICR- FTMS). To support these activities it has been developing computing systems for parallel processing using Transputers, DSPs, Microcontrollers and logic devices. Some highlights of the work done during last year are as follows:

Artificial Neural Networks

The work on artificial neural network continued with simulations being developed for randomly



Various types of decision boundaries obtained by randomly connected neural network



Curves showing speed of convergence of randomly connected neural network and fully connected multilayered network

connected feed forward and feedback networks. The back propagation type training algorithm were developed for randomly connected feedforward network and error convergence was tested on some problems. The properties of the randomly connected networks were studied and the convergence was found to be better than totally connected multilayered network. The following applications were developed using these network architectures.

1. Limited number of human face recognition using randomly connected feed back network is developed. This network permits an input as a partial picture, a noisy picture, a picture offseted or tilted with respect to original training image. Output of the network produces original image with the identification code.
2. Feature wise classification of the land images taken by satellite using combination of Kohonen network and feed forward network.
3. Simulation of the Multilayer Neural Network hardware design for implementation in VLSI.

The Ion Cyclotron Resonance Mass Spectrometer

The ICR-MS is basic tool for research in many fields and application. The ICR-FTMS has many advantages over conventional mass spectrometer, the most important is the whole spectrum obtained from a single excitation of ICR signal by taking Fourier transform of the time domain signal following the excitation. The vacuum system with rotary and sputter ion pump have been fabricated and vacuum of the order of 10^{-7} torr has been obtained, which will be improved to 10^{-8} to 10^{-9} necessary for ICR experiment by adding a turbo- molecular pump. The design of ICR cell and detector electronics is under way.

Hardware Developments

T800 transputer based add-on boards for PC are developed to increase the computational speed and run parallel processing were developed with TRAMS. The work on direct graphics support for transputer based boards is under development using G300 graphics controller. ADC/DAC interfaces were developed on transputer bus for very fast data acquisition by transputer based boards. The technique is very useful for data acquisition and signal preprocessing where only the end results such as FFT could be passed to host for archival or further interpretation.

In yet another development the Intel's versatile microcontroller 8751 were used in a shared memory architecture, where two microcontrollers share the same memory. This will be useful in building low cost neural network hardware with parallel processing.

A facility has been established to develop logic design and implement it in programmable logic devices (PLDs). The programmable logic devices offer several advantages over discrete logic in terms of speed, size and reliability. Their major application will be developing glue logic for high

speed microprocessor and neural network hardware.

List of papers published in 1992-93

1. H.S.Mazumdar, " Randomly Connected Feedback Network for Associative Image Memory", Indian Computing Series; Innovative Applications in Computing Proc. ICC 1992, Tata Mc Graw Hill Publishing Co., New Delhi, 344 (1992)

Library

Collection

The PRL Library subscribes 195 scientific and technical journals. A large number of Scientific Reports, Data, Maps, etc. are also received. Each year over 200 books are added to the Library. The total stock of books and bound volumes of periodicals is over 38,000.

Services

Over 76,000 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 432 publications from other libraries on Inter-Library-Loan. Most of these publications were obtained on loan for our readers. About 300 publications were loaned by us to other libraries.

During the year 7296 books and journals were issued. Several queries are received for providing factual information, locating addresses, giving biodata, preparing bibliographies etc.

Weeding Out

About 1700 books were weeded out from the collection, in consultation with our scientists. This was kept as a separate collection, in order to ensure that there was no demand for these books. After a subsequent checking, subjectwise lists were prepared and circulated to complete the weeding out process. This is the first time that weeding out has been done in the Library.

Current Awareness Services

Two Surveys were undertaken to study the impact of "Research Alert" - a Current Awareness Service, given to over 60 Scientists. Important results of these Surveys showed that :-

- Cost of 4 months time saved by 23 Scientists owing to Research Alert was Rs.10.41 lakhs.
- Twenty one percent of the respondents said that Research Alert enabled them to prevent duplication of research.

Resource Sharing

PRL Library is a member of a global Discussion Group called PAMNET (Phys. Ast. Maths Network) . It is a Library Oriented Computer List, used for sharing information and for asking questions. A similar forum for Phys. Ast. Maths. Librarians in India called PAMINET, has been started mainly for Resource Sharing. Response received has been very encouraging.

Owing to extensive Resource Sharing with some of the local libraries, forty four journals have been discontinued in PRL Library alone costing over ten lakhs. Contents pages and even abstracts of a few important journals, are either received or printed from Current Contents on Disk-PCES. These are filed & displayed alongwith the current journals.

Engineering Services

The Engineering services render all technical services pertaining to Civil engineering works and related building and laboratory services such as electrical, public health, 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, horticul-

tural development and maintenance and upkeepment of various buildings & campuses like PRL Campus, Staff Quarter Campus, Thaltej Campus, Gurushikar and Hill View Observatory, etc. We also prepare sophisticated equipments which meet the clean room specifications.

During the year following works have been undertaken:

- Construction of workshop block at Thaltej Campus.
- Planning & design of proposed optical Aeronomy Observatory Building at Gurushikar, Mt. Abu.
- Site preparation works for :

  Quantulus Liquid Scintillation counting system on 3rd floor.

  Excimer laser and dye laser for laser laboratory on 5th floor.

  Gas chromatograph Mass spectrometer system on 6th floor.

  Computer workstations on 7th floor

  New Digital Ionosonde with microprocessor in Ionospheric

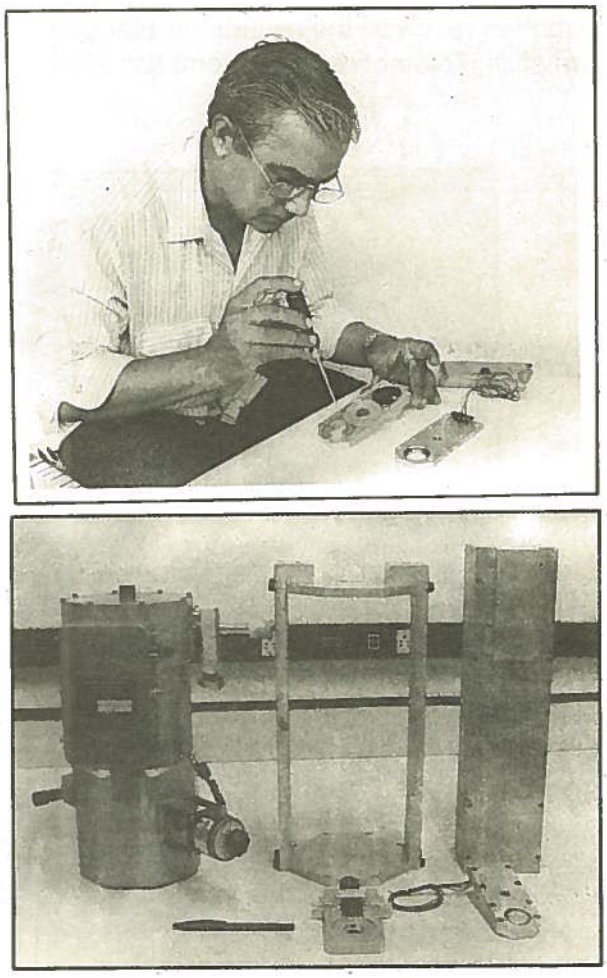
Workshop

The mechanical workshop has extended considerable assistances in the development of new instruments as well as timely maintenance of the mechanisms of various types, integral to the experimental setups. Basic design information has been provided to various groups to help them design their own equipments. The Workshop has also undertaken design and fabrication of total setups such as the 6 metre corer used for sediment collection in Mansar lake near Jammu.

Precision optical assemblies for instruments designed for upper atmospheric studies such as airglow imaging systems, dayglow, Fabri Perot spectrometer were taken up and completed satisfactorily. The instruments were taken to outstation locations and operated sucessfully.

Fabrication of dewar for IR detector needed delicate handling and superior worksmanship. Regular service was extended at Mt. Abu to facilitate experimental work on IR telescope as well as its maintenance. Other precision jobs included balloonborne instruments and sensors for rocket borne plasma experiments.

Many types of items such as lead shields, sample holders, high vaccum valves were fabricated. Fluorescent chamber made of stainless steel and high vaccum system with plasma gun movement mechanism are some moderately largesystems fabricated at PRL workshop. A large number of parts needed for the radio telescope at Thaltej campus was also fabricated.



The assembly and details of the Infrared Polarimeter which was designed and fabricated in the workshop and is an import substitute

Events and Activities 1992 - 1993

On August 12, 1992 the Physical Research Laboratory celebrated the seventythird birth anniversary of its founder Dr. Vikram A. Sarabhai. The celebrations started with the traditional tree planting ceremony at the PRL campus. This was followed by the Vikram Jayanti celebrations in our new auditorium. A book entitled *Vikram Sarabhai - the Man and the Vision*, edited by Dr. Padmanabh Joshi of Nehru Foundation for Development was released by Prof. P. R. Pisharoty who was the chief guest. The presentation of the Shri Hari Om Ashram Prerit Dr. Vikram Sarabhai Research Awards for the year 1991; funded by the Shri Hari Om Ashram of Nadiad, Gujarat and instituted in 1973 by PRL followed. Six scientists received the awards. Shri H. S. Mazumdar of PRL, Ahmedabad and Dr. Shashi Bhushan Sharma of SAC, Ahmedabad received the awards for Electronics, Informatics, Telematics and Automation. Professors Vinod Krishan and R. Sridharan of IIA, Bangalore and PRL , Ahmedabad respectively received the award for Space Sciences. Shri V. R. Katti of ISAC, Bangalore and Shri A. Sivathanu Pillai of DRDO, Hyderabad were awarded the Hari Om medals for Systems Analysis or Management Problems.

Hindi week was celebrated at PRL during the week 14 - 19 September, 1992. Like earlier occasions programmes for the staff members and their families were organised. The programmes included essay competition, lectures, video films and recitation and elocution competition. Prof. Y. C. Saxena of Institute of Plasma Research, Gandhinagar gave an informative talk on Prayogshala mein Antriksha. Another talk on Efficiency, Dedication and India's Future was given by Shri R. N. Mishra.

Prof. P. R. Pisharoty presenting the Shri Hari Om Ashram Prerit Dr. Vikram Sarabhai Research Awards for the year 1991 to Prof. Vinod Krishan.

This year the 58th Annual Meeting of the Indian Academy of Sciences was held at the Physical Research Laboratory and Space Applications Centre, Ahmedabad during 6-9 November. This year's meeting included a discussion on the state of science in the country and a series of talks on the Earth and its Environment which featured a large number of eminent scientists from the country. There were also a number of technical lectures by young scientists. In addition, there were two public lectures. Prof. K. Kasturirangan, Director, ISRO Satellite Centre, Bangalore delivered a talk on November 6 on *Some Interesting Problems in the Development of ISRO Satellites*. On November 7, Prof. S. R. Rao, Advisor, NIO, Dona Paula talked on *Gujarat through Ages*. Both the talks were held at the PRL Auditorium. A trip to Lothal was also organised to expose the Academy Fellows to the rich heritage of Gujarat, especially the Harappan Civilisation.

In order to stress the importance of Helioseismology and discuss the major goals and achievements of the Global Oscillation Network Group (GONG) programme, an Instructional Workshop on Helioseismology was held at the Physical Research Laboratory, Ahmedabad during January 4 - 9, 1993. A total of seventeen lectures on various aspects of helioseismology were presented. Some of the topics covered during the workshop were solar structure models, astroseismology, solar convection zone dynamics, instrumentation and data analysis. There were thirty five participants from nine institutes in India.

The National Science Day was celebrated on February 28, 1993 at PRL. Every year this day is dedicated to the school children and their teachers. Programmes like Science Quiz, popular science lectures and video shows are arranged with the sole aim of creating scientific awareness amongst

The inaugural function of the Symposium on Futuristic Perspective in Aeronomy and Atmospheric Science Research in India to mark the Centenary Birth celebration of Prof. K. R. Ramanathan, the first director of PRL

the school students. This year a new programme, the Science Manch, was introduced where the science teachers interacted with a panel of academicians consisting of scientists from PRL and professors from Universities. One hundred and fifty students and seventy five teachers from different schools of Ahmedabad and Gandhinagar districts participated in the Science Day Function. The celebration was organised in collaboration with the Indian Physics Association and Gujarat Science Academy.

The laboratory celebrated the birth centenary of Prof. K. R. Ramanathan, the doyen of meteorology and atmospheric science and its first director on March 23, 1993 which happened to be the World Meteorological Day. To commemorate this day, PRL organised a two day symposium on Futuristic Perspectives in Aeronomy and Atmospheric Science Research in India. Sixteen invited lectures were presented in the fields of Meteorology, Atmospheric Sciences, Ionosphere / Upper Atmosphere and Geomagnetism. These were the fields in which Professor Ramanathan was interested and had conducted pioneering work. These lectures discussed the possible future directions of research in the country over the next decade. The centenary celebration was inaugurated by Prof. U. R. Rao, Chairman, Indian Space Research Organisation. About one hundred and eighty delegates including Prof. Ramanathan's old associates and students attended the celebrations. Prof. Rao also dedicated the newly built auditorium to the memory of Prof. Ramanathan, after whom the auditorium has been named.

The Fifth K. R. Ramanathan Memorial Lecture was delivered by Dr. K. Kasturirangan, Director, ISRO Satellite Centre, Bangalore on March 23, 1993. Delivering the memorial lecture on Space Platforms for Scientific Research, Dr. Kasturirangan brought out the relevance of many of Professor Ramanathan's earlier works in the context of investigations involving satellite observations of the related phenomena, such as the aerosol loading due to volcanic eruptions, use of long wave radiation to study the monsoon phenomenon and stratospheric ozone studies. He also discussed the prospect of

Dr. K. Kasturirangan, Director, ISRO Satellite Centre, Bangalore delivering the Fifth K. R. Ramanathan Memorial Lecture

conducting more refined and detailed studies on many of the above aspects from space platforms in future in India.

A miniworkshop on High Resolution Astronomical Spectroscopy in the Optical and Near IR was held at Hillview, Mt. Abu during March 22 - 25. This was jointly organised by IUCAA and PRL. Some twenty five participants from different institutes participated. The proceedings were mostly the invited talks. Participants also visited the Gurushikhar observatory on afternoon. This was the first academic meeting to be held at Mt. Abu observatory.

This year nine of our staff members retired from PRL. Shri V. M. Thaker, Sanitary Supervisor, retired from services on May 21, 1992. Shri Thaker had joined our Laboratory on November 3, 1972 as Cleaning Supervisor. Before joining PRL, Shri Thaker had worked from 1960 - 1968 in Kenya and Uganda in various capacities as Health Inspector, Malaria Inspector and Mosquito Control Officer. Shri Thaker was quite hard working and meticulous in his work. Apart from his routine work, he was quite interested in educating his colleagues and society in general about prevention of malaria. He very often wrote in newspapers on tackling malaria through control of mosquitoes. We wish a very long and healthy retired life for Shri Thaker with his family.

Shri Valerin Pinto was born on May 1,1942 at Mangalore. He did his matriculation in the year 1959 and joined PRL in 1969 as Assistant Canteen Supervisor. In 1977 he became the Assistant Canteen Manager. During his tenure at PRL he rendered his services in PRL General Canteen, Faculty Canteen, Dining Hall and Guest House. He was found very hard working and sincere throughout his service career with us and was always ready to serve without any hesitation. His gentle nature and kind and cooperative approach won the affection of all of us. He has taken voluntary retirement from March 31, 1992. We wish him a long happy life.

Our Medical Officer, Dr. Jagdishchandra Kantilal Shah retired from PRL on July 31, 1992 after a distinguished service spanning about twenty five years. When Dr. Shah joined PRL in the year 1968, the laboratory was relatively smaller in size and staff and the people were treated by a small dispensing outfit comprising of Dr. Shah and a compounder. Since then PRL has grown in size and today we have about six hundred staff members and their families, During the years Dr. Shah built up in the PRL quarters, a full-fledged dispensary which has two doctors, a nurse, two pharmacists, a laboratory assistant (medical) besides a cleaner. He has also taken a leading role in implementing the contributary health scheme in PRL. The fact that we have had a good and medically healthy laboratory speaks of the good work of Dr. Shah over the years. We wish him a long, healthy and happy life with his family.

Shri T. M. Raval retired on July 31, 1992 after completing 31 years of service at PRL. Shri Raval joined on August 1 as a Technical Assistant in the Cosmic Rays group where he was entrusted with the maintenance of the cosmic ray cube unit. Later he was transferred to the ISIS project. While working at PRL Mr. Raval joined the first batch of Part time Diploma Course in Electrical Engineering at the Government Polytechnic and passed with distinction. From September 1973 he was associated with the Rocket Aeronomy group and was associated with fabrication of rocket payloads which were being

developed at PRL. Most of these work involved painstaking and careful handling and Shri Raval displayed very neat workmanship. He was very keenly interested in staff welfare and was the first secretary of the Staff Welfare Association at its formation and later on also of the PRL Employees Union. We wish him a long, happy and peaceful retired life.

After a long and fruitful career of 15 years Prof. R. N. Keshavamurty took voluntary retirement from PRL in July 1992. This followed his appointment as the Director, Indian Institute of Tropical Meteorology, Pune, a premier institute in meteorology.Dr. Keshavamurty's scientific career is a long inning spanning more than three decades. He opened his career in the India Meteorological Department in 1959. He joined PRL in 1977. He shaped a group of young scientists who conducted many important and central problems in monsoon dynamics. For Dr. Keshavamurty monsoon has been the fascination of his life. Over the years at PRL he has been able to transform this fascination into important contributions in the field. He was awarded the first B. N. Desai Gold Medal for his paper in 1968. He won the first Hari Om Ashram Prerit Dr. Vikram Sarabhai Award in 1975. He was invited by WMO as a consultant to lecture on Tropical Meteorology at Singapore in 1970 and at Dhaka in 1981. He was member of the prestigious WMO/ICSU Joint Scientific Committee during 1987 - 90. He was President of the Indian Meteorological Society - Ahmedabad Chapter during 1987 - 89. He is a Fellow of the National Academy of Sciences, India.

Shri Banshidhar retired from PRL in 1992 after twenty three years of dedicated service. Born on December 1, 1932 he had his education in Allahabad. After a brief service in the Electronics industry Mr. Banshidhar joined PRL in 1965. Initially he was responsible for the maintenance of

ionosonde. When the rocket era came in India, Mr. Banshidhar meticulously designed and sucessfully flew a High Frequency Capacitance Probe from Thumba. When the need for measurement of absorption in the equatorial ionosphere arose Mr. Banshidhar designed three Riometers (Relative Ionospheric Opacity Meter). These Riometers gave excellent and continuous equatorial ionospheric absorption data which was not available at that time. During the era of satellites he was involved with the designing and fabrication of instruments to study the ionospheric beacon transmission for various satellites. Later Mr. Banshidhar shifted his interest to the optical and near infrared studies. He sucessfully completed a polarimeter in the optical region for studies of interstellar objects. Later he developed a CCD camera. Mr. Banshidhar had tremendous team spirit and extreme dedication which enabled him to complete projects on or even before the deadlines.

Prof. D. P. Agrawal, Senior Professor and Area Chairman, Continental Palaeoclimate Studies Area superannuated on March 31, 1993 after an illustrious scientific career spanning more than three decades. An archaeologists by training, he began his career at the Tata Institute of Fundamental Research, Bombay where jointly with Dr. Shiela Kusumgar and Prof. D. Lal, he was largely responsible for providing a firm chronological frame work for Indian Archaeology. Subsequently he contributed to the understanding of the metallurgical skills of the prehistoric man and the technical evolution of the Stone Age man. Prof. Agrawal came to PRL in 1973 and here he primarily concerned himself with the Palaeoclimatic Studies in PRL and

in India. PRL 's work on Quaternary deposits of the Karewas of Kashmir was co-ordinated and led by him. He has authored several original books, edited conference proceedings and has published over 200 scientific articles. He was elected as the fellow of the National Academy of Sciences, Allahabad. He is one of the members of the editorial boards of several foreign research journals, besides being a member of various international and national academic commissions and committees. Prof. Agrawal is also the Chairman of the Indian Society for Prehistoric and Quaternary Studies.

Shri R. S. Panchal retired from PRL on March 31, 1993. He was born in 1933 in a Panchal family. It is said that a child born in a Panchal family is a born mechanic. This statement is very true for Mr. Panchal. He has an inherent aptitude and ability for repairing machines and instruments. Before

joining PRL, Mr. Panchal was working as a mechanic in a wellknown wall clock manufacturing company. In PRL he was attached to the ISIS Project. He has fabricated various types of Antenna and other instruments. After the ISIS project wound up he was absorbed in the general workshop. He was equally useful here for precision turning work, rocket nose cone assembly and other jobs which bears testimony of his fine work. During the later part of his service he was assigned the responsibility of servicing, repairing and maintenance of the machines in the workshop. Mr. Panchal will be remembered by many staff members for the voluntary service extended by him for repairng wrist watches.

Papers Presented at Symposia/Conferences In 1992-93

ASTRONOMY AND ASTROPHYSICS

a. 1992 STEP Symposium, Kossiakoff Center, Applied Physics Laboratory, John Hopkins University, August 24-28, 1992.

1. Hari Om Vats, "Solar Wind Measurement in India".

b. IAU Colloquium No.141, on Solar Magnetic and Velocity Fields, Beijing, China, September, 6-12, 1992.

1. A.Bhatnagar and Nandita Srivastava, "Magnetic Field Configuration in Flare Loops and Flaring arches".

c. Seventh National Symposium on Science and Technology of Plasmas (Plasma - 1992), Bombay, November 3-8, 1992.

1. Tripathy, S.C., "Study of instabilities at the inner edge of the accretion disk".

d. International Astronomical Union's Symposium No: 158 on Very High Angular Resolution Imaging, Sydney, Australia, 11- 15 January 1993.

1. T.Chandrasekhar, N.M.Ashok and Sam Ragland, "Near Infrared High Angular Resolution observations of Stars and Circumstellar regions by the technique of Lunar occultations".

e. Winter School on Optics ICTP, Trieste, Italy, February 8-26, 1993.

1. Debi Prasad C., "Use of Fabry-Perot etalons in Astronomy".

f. All India Amateur Astronomers Meet, Community Science Centre, Ahmedabad, February 12-14, 1993.

1. U.C.Joshi, "Amateur Astronomers and Hubble Space Telescope" (Invited talk).

g. Indian Academy of Sciences - 58 Annual Meeting - Symposium on Interactive Processes in Near Earth Environment, PRL Ahmedabad, 6-10 November, 1992.

1. T.Chandrasekhar, "Comets as Probes of the Interplanetary Medium", (Invited talk).

h. Astronomical Society of India - Fifteenth Meeting, Bombay, 2-5 March, 1993.

1. B.G.Anandarao, Imaging Studies in the Infrared Region (Invited Review talk).
2. A.Bhatnagar, "GONG project for helioseismology"(invited review talk).
3. N.M.Ashok, T.Chandrasekhar, Sam Ragland, and P.V.Watson, "Near-Infrared Photometry of Unassociated IRAS point sources in the Zodiacal belt".
4. A.Chakraborty, B.G.Anandarao and R.Swaminathan, "Ultra-Rapid Variability in H-alpha Emission Line Profiles in Gamma Cassiopeiae and lambda Eridani".
5. T.Chandrasekhar, Ashok N.M., and Sam Ragland, "Near Infrared Coronal line Emission in Nova Herculis 1991".
6. T.Chandrasekhar, N.M.Ashok, and Sam Ragland, "Near Infrared High Angular Resolution Observations of Stars and Circumstellar Regions by the technique of Lunar Occultations".
7. J.N.Desai, "1.2 Meter Infrared Telescope at Gurushikhar" (Invited talk).
8. M.R.Deshpande, Hari Om Vats, Janardhan P. and Bobra A.D., "Observations of PSR 0950+08 at 103 MHz".
9. M.R.Deshpande, and U.C.Joshi, "On the nature of Radiation from the Nuclei of cD galaxies".
10. M.R.Deshpande and U.C.Joshi, "Possible evidence for Nonthermal Radiation from the Nuclei of Seyfert Galaxies".
11. R.M.Jain and V.K.Kumawat, "Solar Proton Flare of November 15, 1989".
12. U.C.Joshi, "Recent Developments in Optical and Infrared Polarimetery" (Invited Review Talk).
13. U.C.Joshi, J.S.Chauhan, M.R.Deshpande, A.K.Sen and A.K.Bhatnagar, "Imaging Polarimetry of Comet Austin".
14. P.Seema, D.P.K.Banerjee and B.G.Anandarao,"Velocity Field Structure in the Orion Nebula".
15. D.B.Vaidya and B.G.Anandarao, "Interstellar Grains in the Regions of Anomalous Extinction".
16. Hari Om Vats, M.R.Deshpande, Janardhan P. and Harish Chandra,"Terrestrial Effects of PSR 0950+08".

i. Workshop on the proposed Astronomical Observatory at Panchmarhi at Bhopal, on 19 to 22 March, 1993.

1. A.Bhatnagar, "Infrastructure Required for a New Observatory".

j. IUCAA -PRL Mini-workshop on Techniques for Astronomical High Resolution Optical & IR Spectroscopy held at Mt.Abu, March 22-26, 1993.

1. B.G.Anandarao, a) "Interferometric Spectros copy" and b) "High-resolution Imaging"
2. N.M.Ashok, "Single Element Detectors for Spectroscopy"
3. T.Chandrasekhar, a) "Two Dimensional Detectors in Astronomy" and b) "High Resolution Spectroscopy in the Infrared
4. Debi Prasad C., Spatial Heterodyne Spectroscopy"
5. J.N.Desai, a) "Fourier Transform Spectroscopy - Principles" and b) "Fourier Transform Spectroscopy - Design"

k. K.R.Ramanathan Centenary Symposium on Futuristic Perspectives in Aeronomy and Atmospheric Science Research in India, PRL, Ahmedabad, March, 22-23.

1. J.N.Desai, "Optical Sounding of the Upper Atmosphere (Invited Talk)

l. **Interchapter Meeting of IPA (Gujarat Chapters), M.G.Sci. Institute, Ahmedabad, 22 November, 1992.**

1. J.N.Desai, "M.N.Saha and Astronomical Spectroscopy" (Invited Talk).

PLANTERY ATMOSPHERE AND AERONOMY

a. **Symposium on 1992 International Quadrennial Ozone, Charlottesville, Virginia, USA, June 1992.**

1. Lal, M., Chakrabarty, D.K., Sidhu, J.S. and Das, S.R., "Near simultaneous measurements of NO_2, NO_3 and H_2O by ground-based absorption spectroscopy technique".
2. Lal, M. and Chakrabarty, D.K., "Derivation of water vapour cross-section in the red region".

b. **29th COSPAR Meetings, Washington D.C., USA, August 28-September 5, 1992.**

1. Jayaraman, A. and Subbaraya, B.H., "Tropospheric aerosol extinction profiles and their seasonal variability over tropical India".
2. Haider, S.A., "A comparative study of daytime and nighttime ionosphere of Mars".
3. Sridharan, R., Sekar, R., Gurubaran, S., Narayanan, R. and Modi, N. K., "First results from a high resolution Doppler imaging spectrometer from the region of equatorial ionization anomaly".
4. Gurubaran, S., Sridharan, R., Narayanan, R., Sekar, R. and Modi, N.K., "The low latitude thermosphere/ ionosphere system".

c. **Fourth Annual Conference of Indian Aerosol Science and Technology Association, National Institute of Occupational Health, Ahmedabad, October 12-13, 1992.**

1. Jayaraman, A., Acharya, Y.B., Chandra, H. and Subbaraya, B.H. "Nd-YAG lidar observations of stratospheric aerosol layers over Ahmedabad".
2. Ramachandran, S., Jayaraman, A., Acharya, Y.B. and Subbaraya, B.H., "Balloon-borne measurements of Mt. Pinatubo aerosol layer at stratospheric altitudes over Hyderabad".
3. Bhattacharya, Y., Ramachandran, S. and Jayaraman, A., "Ground based study of atmospheric aerosol using a combination of sun tracking photometer and a low pressure Anderson Impactor".
4. Jayaraman, A., Shibu John and Verma, S.D., "Lidar probing of atmosphere : Estimation of back scattered signal strength".
5. Jayaraman, A., Clement, C.J., and Verma, S. D., "Study of aerosol using INSAT data : Calculation of favourable observation time".

d. **58th Annual Meeting of the Indian Academy of Sciences, PRL, Ahmedabad, November 6-9, 1992.**

1. Jayaraman, A.,"Middle Atmosphere Coupling Processes"
2. Sridharan, R., "Ionosphere-thermosphere coupling". (Invited talk).

e. **Winter School on Understanding the Climate and its Future Change over the Indian Sub-Continent due to Global Warming, Delhi, December 7-24, 1992.**

1. Shyam Lal, "Greenhouse effect and global warming potentials of trace gases".

f. **First Workshop on ISRO-GBP Results, ISRO Headquarters, Bangalore, February 25-26, 1993.**

1. Jayaraman, A., Subbaraya, B.H. and Bhattacharya,Y., "Retrieval of aerosol optical depth over ocean surfaces using AVHRR data".
2. Subbaraya, B.H., Shyam Lal, Modh, K.S. and Manish Naja, "Surface ozone monitoring at Ahmedabad".
3. Shyam Lal, Subbaraya, B.H. and Venkataramani, S., "Vertical distribution of CFCs, HCFCs and other trace gases over the tropics obtained from the ballcon measurements conducted from Hyderabad".
4. Venkataramanai, S., Shyam Lal and Subbaraya, B.H., "Methane flux measurements from paddy fields in Thanjavur region".

g. **ALL India Seminar on Integrated Electronics, Roorkee University, Roorkee, Organised by Institution of Engineers (India) and I.E.E.E. (UP Section), March 20-21, 1993.**

1. Mirsa, R.N., "Frame Buffer for Slow Scan CCD Camera".

h. **Second SERC School on Atomic/Molecular Physics, Roorkee, March 1993.**

1. Vijay Kumar, Gave six lectures on "Ion-Molecule Reactions at Thermal Energies".

EARTH SCIENCES AND SOLAR SYSTEM STUDIES

Geocosmophysics

a. **International Seminar on Problems of Deserts and Saline Playas, Yazd, Iran, May 15-19, 1992.**

1. Singhvi, A.K. "Thermoluminescence".

b. **55th Meteoritical Society Meeting, Copenhagen, Denmark, July 27-31, 1992.**

1. Bhandari, N., Bonino, G. and Castagnoli, G.C., "Cosmogenic effects in Bouvanite Chondrite".
2. Murty, S.V.S. and Bhandari, N. "Light nitrogen in Lehrauli Urelite".

3. Murty, S.V.S., Srinivasan, G. and Goswami, J.N."Nitrogen and noble gases in microdiamonds from Murchison".

c. **Symposium on Antarctic Meteorites, National Institute of Polar Research, Tokyo, Japan, August 17-20, 1992.**

1. Murty, S.V.S. and Bhandari, N. "Noble gases and nitrogen in Lehrauli Urelite".

d. **29th International Geological Congress, Kyoto, Japan, August 24-30 September 1992.**

1. Bhandari, N., Shukla, P.N. and Azmi, R.J. "Positive Eu anomaly at the Permo-Triassic boundary, Spiti, India.
2. Bhattacharya, S.K., Sarkar, A., Juyal, N. and Yadav, M.G. "Signature of Younger Dryas Cooling in the Arabian Sea Sediments".
3. Krishnaswami, S., Trivedi, J.R., Pande, K., Sarin, M.M. and Ramesh, R. "Sr isotopes U and Rb budgets in the ocean : Role of Himalayan rivers".
4. Pant, R.K. and Juyal, N. "Radiometric dating of late Quaternary sea levels from Saurashtra Coast, West Coast of India.
5. Singhvi, A.K.,"Origin, evolution and paleoenvironmental history of the Thar desert, Rajasthan, India".

e. **Symposium on Some Aspects of Chemistry of the Northern Indian Ocean, NIO, Goa 28 August, 1992.**

1. Chakraborty, S., Ramesh, R. and Krishnaswami, S. "Radiocarbon and oxygen isotopic records of sclerectinian corals from the Arabian Sea : Historical climatic data and air-sea CO_2 exchange".
2. Ramesh, R. and Lal, D. :A critical analysis of the processes governing the nutrient profiles in the ocean".
3. Sarin, M.M. and Church, T.M. "Estuarine behaviour of ^{234}Th, ^{228}Th, ^{210}Po and ^{210}Pb : Implications regarding the fate of reactive elements".
4. Somayajulu, B.L.K. "Uranium isotopes in the Hooghly estuary, West Bengal".

f. **International Symposium on Himalayan Geology, Shimane, Japan, September 3-9, 1992.**

1. Bhandari, N., Shukla, P.N. and Azmi, R.J., "Geochemical clues to the origin of the limonitic layer at the P-Tr boundary, Spiti".
2. Pant, R.K., "Loess deposits of north western Himalaya : Chronology and paleoclimatic significance".

g. **ESCA/ERF Conference on Changes in Fluxes in Estuaries : Implications from Science to Management held in Plymouth, UK, September 13-18, 1992.**

1. Sarin, M.M. and Church, T.M. "Radionuclide studies of estuarine phase transfer processes".

h. **33rd Annual Meeting of the Geological Society of India on Rock Weathering and Soil formation, Pune, September 21-23, 1992.**

1. Somayajulu, B.L.K., Sarin, M.M., Rengarajan, R. and Radhakrishna, B.P. "Preliminary investigation of Karnataka laterites for U decay series nuclides and composition".

i. **Research Coordination Meeting/Workshop on Isotopic Variations of Carbon Dioxide and Other Gases in Atmosphere, Heidelberg, Germany, November 2-5, 1992.**

1. Bhattacharya, S.K. and Francey, R. "Monsoon effect on atmospheric carbon dioxide".

j. **Workshop on Coral Paleoclimate Reconstruction, La Paraguera, Puerto Rico, USA, November 5-8, 1992.**

1. Chakraborty, S. "Stable and radio-isotope-systematics in corals from the Arabian Sea : Implications to Climate".

k. **International Conference on the Inter-relationship between Mountain Uplift, Chemical Weathering and Climate, Lamont- Doherty Geological Observatory, New York. November 9-10, 1992.**

1. Pande, K. "Himalayan tectonics and the marine $^{87}Sr/^{86}Sr$ record : Role of Ganga and Indus Systems".

l. **International Symposium on Snow and Gacier Hydrology, Kathmandu, Nepal, November 16-21, 1992.**

1. Nijampurkar, V.N., "Review of ice dynamics and climatic variation studies on Himalayan glaciers based on stable and radioisotope studies during the past decade".

m. **Workshop Meeting to Identify Thrust/gap Areas in Palaeoclimatology, IITM, Pune, January 21-22, 1993.**

1. Bhattacharya, S.K. and Somayajulu, B.L.K., Quaternary climatic changes : reliability of data and analysis.
2. Ramesh, R. High resolution climatic signals from stable isotope studies of tree rings and corals.

n. **National Seminar on Environment, Defence Laboratory, Jodhpur, January 27-30, 1993.**

1. Singhvi, A.K. "Geological and palaeoenvironmental studies using luminescence dosimetry of natural radiation environment".

o. **First Workshop on ISRO-GBP Results, February 25-26, 1993.**

1. Ramesh, R. "Stable Isotope studies of Indian trees and corals under IGBP PAGES stream 1 for their paleoclimatic potential".
2. Ramesh, R. "Air-sea exchange of carbon dioxide:Model calculations.

3. Somayajulu, B.L.K.,"Paleoclimatic records".

p. **25th Lunar and Planetary Science Conference, Houston, Texas, USA, March 15-19, 1993.**

1. Goswami, J.N., Srinivasan, G. and Ulyanov, A.A. "Grosnaja ABCs:" Magnesium isotopic variations".
2. Murty, S.V.S. "Nitrogen and light noble gases in Parsa enstatite chondrite"

q. **Workshop on River Basins of India, JNU, New Delhi, March 23-24, 1993.**

1. Sarin, M.M. "Weathering in the Himalayas : Fluxes of Sr and U isotopes to the oceans and their global implications.

Continental Palaeoclimate Studies

a. **Symposium on Himalayan Geology, Shimane, Japan, September. 6-8, 1992.**

1. Agrawal, D.P., Deshpande, R.D. and Kusumgar, Sheela, "Late Cenozoic Climatic Change in Kashmir Himalayas".

b. **International Symposium on Nature and Humankind in the Age of Environmental Crisis, Kyoto, Japan, September 28-October, 4, 1992.**

1. Agrawal, D.P., "Nature and Humankind in the Indus Civilization - Environmental and Civilizational Processes in India: Their Global Relevance".

c. **IIT Winter School, November, 1992, Delhi.**

1. D.P. Agrawal, "Past climatic changes in India and their relevance to global warming".

d. **Annual Congress of Indian Society for Prehistoric & Quaternary Studies, Dharwad, November ,1992.**

1. D.P. Agrawal, "Presidential Address".

e. **Workshop on Past Global Climatic Changes, Pune, January, 21-22, 1993.**

1. D.P. Agrawal, "Climatic Changes since the last Glacial Maximum"

f. **Conference on Origin of Urbanisation, in Eastern Africa, Mombasa, Kenya, January, 25-29, 1993.**

1. D.P.Agrawal, "The Role of Environmental Technology changes in a Global Perspective".

h. **Western Pacific Geophysics Meeting, AGU, Hong-Kong, August ,17-21, 1992.**

1. Gupta, S.K. and Sharma, P., "Ice Age Glaciation of Tibetan Plateau", Abstract No. A31A-6".
2. Gupta, S.K., "Groundwater Tracing with Injected Helium", Abstract No. H31-A-3.
3. El-Kadi, A.I., Lau, L.S. and Gupta, S.K., "Modelling solute transport in Hawaiian basalt aquifer by using Helium as environmental tracer", Abstract No. H31-A-4.

THEORETICAL PHYSICS

Meteorology and Climate Studies

a. **First Workshop on ISRO-GBP results, ISRO Head Quarters, Bangalore, February 25-26, 1993.**

1. Satyan, V., Kasture, S.V. and Thomas, B., "Climate Modelling for GBP related studies".

Plasma Physics

a. **58th Annual Meeting, Indian Academy of Sciences, PRL, Ahmedabad, November 6-9, 1992.**

1. B. Buti, "Solar-Wind Magnetosphere Interactions" (invited talk).

b. **1992 WPGM Meeting, Hong Kong, August 17-21, 1992.**

1. B. Buti, "Irregularities in Lower Ionospheric Plasma" (invited talk).

c. **Plasma-92, 7th National Symposium on Science and Technology of Plasmas, Bombay, November 3-7, 1992,**

1. B. Buti, Magnetospheric Reconnection (invited talk).

d. **VII National Symposium on Science and Technology of Plasmas University of Bombay, Vidyanagari, Bombay, November 3— 7, 1992.**

1. N.N. Rao, "Low—Frequency Waves in Magnetized Dusty Plasmas" (invited talk).

Atomic and Molecular Physics

a. **XIII th International Conference on Atomic Physics, Munich, Germany, August 3 -7, 1992.**

1. Sheorey, V. B., Localised eigenstates in chaotic quantum systems.

b. **IX th National Conference on Atomic and Molecular Physics, Bombay, December 14 -18, 1992.**

1. Raje N. and Sheorey, V. B., Visualization of wave function of chaotic quantum systems, (Invited Talk).

Classical and Quantum Mechanics

a. **XII th Annual International Conference Dynamic Days Arizona, Tempe, Arizona, USA, January 6 - 9, 1993.**

1. Sheorey, V. B., Structures in high excitation eigenstates of chaotic quantum systems.

Nuclear Physics

a. **Symmetries in Science Vii: Spectrum Generating Algebras and Dynamic Symmetries in Physics, Nakajo, Niigata, Japan, August 28-31, 1992**

1. Kota, V.K.B. and Devi, Y.D., "Dynamical symmetries in the sdg interacting boson model" (Invited Paper)

b. DAE Symposium on Nuclear Physics, Bombay, December 21-24, 1992.

1. Jain, K. and Majumdar, D., "Application of spectral averaging theory for state and level densities to 56Fe nucleus".

c. IUCDAEF(Calcutta Centre) Workshop on Nuclear Structure Physics, Puri, March 5-7, 1993.

1. Kota, V.K.B., "Dynamical symmetries in nuclear structure: new application" (Invited Talk).
2. Devi, Y.D. and Kota, V.K.B., "sdg Interacting boson model: quasi-particle extensions" (Invited Talk by Y.D. Devi).

d. Symposium on Recent Trends in Nuclear Physics, Tirunelveli, March 15-18, 1993.

1. Kota, V.K.B., "Recent developments in statistical nuclear spectroscopy: level densities" (Invited Talk).

Particle and Fields

a. X DAE Symposium on High Energy Physics, TIFR, Bombay, December 1992.

1. Joshipura, A.S. and Rindani, S.D., "Fast neutrino decay in the minimal sea-saw model".
2. Joshipura,A.S. and Rindani, S.D., "Majoron models and the Higgs search".
3. Sarkar, U., "LEP Constraints on Grand Unified Theories" - (invited talk).
4. J.C. Parikh, "Pair Production in Non-Abelian Gauge Fields".

b. International Conference on Physics and Astrophysics of Quark Gluon Plasma, Calcutta, January 19-23, 1993.

1. J.C. Parikh, "Pre-equilibrium Collective Non-Abelian Phenomena in quark-Gluon Plasma" (Invited Talk).

c. International Nuclear Physics Conference, Wiesbaden, Germany, July 26 (1992).

1. S.B. Khadkikar and K.B. Vijayakumar, "Effect of Exchange of Confined Gluons on N-N Scattering".
2. S.B. Khadkikar and J.C. Parikh, "EOS for QGP in a Relativistic Confinement Model".

d. DAE Symposium on Nuclear Physics, Bombay, December, 21-24, 1992.

1. S.B. Khadkikar, C.R. Praharaj and A.K. Rath, "Moment of Inertia of Rotational Nuclei in Hartree-Fock Approximation".
2. S.B. Khadkikar and P.C. Vinodkumar, "Fluctuations of Yang-Mill's Fields Around Classical Background - A strong basis for confinement model".
3. P.C. Vinodkumar and S.B. Khadkikar, "A confining gauge for confining models".
4. K.B. Vijaya Kumar, A.K. Rath and S.B. Khadkikar, " Meson Spectroscopy with COGEP".

ELECTRONICS LABORATORY

a. Indian Computing Congress, Secunderabad, December 19, 1992.

1. H.S. Mazumdar, " Randomly Connected Feedback Network for Associative Image Memory"

b. The sixth International Conference on VLSI Design, Bombay, January 3 - 6, 1993

1. H.S. Mazumdar, "A Multilayered Feed Forward Network Suitable for VLSI Implementation".

Subrat Sarangi

Microscope Basis for IBM; Study of Vibrational and Rotational Nuclei (September 1992).

Symposia / Workshop Organised at PRL

1. 58 th Annual Meeting of the Indian Academy of Sciences; 6 - 9 November, 1992

2. Instructional Workshop on Helioseismology, 4 - 9 January, 1993

4. Miniworkshop on High Resolution Astronomical Spectroscopy, March 22 - 25, 1993.

Symposium on Futuristic Perspectives in Aeronomy and Atmospheric Science Research, 23 - 24 March, 1993.

Conferences/Symposia Attended during 1992-93

ASTRONOMY AND ASTROPHYSICS

Dr.B.G.Anandarao
Dr.N.M.Ashok
Dr.A.Bhatnagar
Mr.A.Chakraborty
Dr.J.N.Desai
Dr.M.R.Deshpande
Dr.R.M.Jain
Dr.U.C.Joshi
Mr.Shibu K.Mathew
Dr.H.O.Vats

Bombay

XV Meeting of the Astronomical Society of India, held at BARC, Bombay, March 2-5, 1993.

Dr.B.G.Anandarao
Dr.N.M.Ashok
Dr.T.Chandrasekhar
Dr.Debi Prasad C.
Dr.J.N.Desai
Dr.K.P.Raju
Mr.S.D.Rawat
Mr.R.J.Shah
Mr.D.V.Subhedar

Mt. Abu

IUCAA-PRL Miniworkshop on Techniques for Astronomical High Resolution Optical and IR Spectroscopy at I.R.observatory, Mt.Abu, 22-26 March, 1993.

Dr.J.Anosova
Dr.M.R.Deshpande
Dr.U.C.Joshi

Pune

International workshop on Galaxy Distribution Functions, December 13-23, 1993: IUCAA, Pune.

Dr.A.Bhatnagar
N.Srivastava

Beijing, China

Solar Magnetic & Velocity Fields, September 6-12, 1992.

Dr.A.Bhatnagar

Boulder, USA.

GONG 1992: Seismic Investigation of the Sun and the Stars, August 11-14, 1992.

Dr.A.Bhatnagar

Bhopal

Workshop on Proposed Astronomical Observatory at Panchmarhi, March 12-19, 1993.

Dr.A.Bhatnagar
Dr.R.M.Jain
Dr.K.P.Raju
Dr.Debi Prasad C.
Dr.S.C.Tripathy
Ms.N.Srivastava
Mr.Shibu K.Mathew

Ahmedabad

Instructional Workshop on Helioseismology, PRL, January 4-8, 1993.

Dr.B.G.Anandarao
Dr.N.M.Ashok
Mr.A.Chakraborty
Dr.T.Chandrasekhar
Dr.J.N.Desai
Dr.M.R.Deshpande
Dr.U.C.Joshi
Mr.S.Ragland
Dr.K.P.Raju
Ms.P.Seema
Dr.H.O.Vats
Mr.P.Watson

Ahmedabad

58th Annual Meeting of the Indian Academy of Sciences, held at PRL, November 6-9, 1992.

Dr.T.Chandrasekhar

Sydney, Australia

International Astronomical Union, Symposium No.158 on Very High Angular Resolution Imaging, Sydney, Australia, 11-15 January, 1993.

Mr.A.Chakraborty

Pune

First SERC school in Astronomy & Astrophysics on the topic Active Galactic Nuclei, at IUCAA, Pune, during 22 November to 12 December, 1992.

Dr.Debi Prasad C.

Trieste, Italy

Winter College on Optics, February 8-26, 1993.

Dr.M.R.Deshpande
Dr.U.C.Joshi

Pune

IUCAA Buildings' Dedication Ceremony : December 28, 1993 and Dedication Seminar, IUCAA, Pune, December 29-30, 1993.

Dr.U.C.Joshi

Ahmedabad

All India Amateur Astronomers' Meet, February 12-14, 1993, Community Science Centre and PRL, Ahmedabad.

Mr.Sam Ragland
Dr.S.C.Tripathy
Mr.Watson P.V.

Siliguri

Advance Graduate School on "Relativistic Astrophysics, Gravitation and Cosmology", North Bengal University, Siliguri, October14-November 3, 1992.

Dr. Hari Om Vats

Baltimore, USA

1992 STEP Symposia/5th COSPAR Colloquium, John Hopkins University, Baltimore, August 24-28, 1992.

Ahmedabad

Instructional Workshop on Helioseismology, held at PRL, Ahmedabad, January 4-9, 1993.

Dr.Hari Om Vats

Mr.A.D.Bobra

Mr.K.S.Lali

Ahmedabad

Futuristic Perspectives in Aeronomy and Atmospheric Science Research in India, held at PRL, March 22-23, 1993.

Dr.J.N.Desai

Dr.M.R.Deshpande

Dr.U.C.Joshi

Dr.H.O.Vats

Ahmedabad

Interchapter Meeting of the Indian Physics Association (Gujarat Chapters), MG Science Institute, Ahmedabad, November 22, 1992.

Mr.A.D.Bobra

Ahmedabad

Attended Residential Course on "Computer Networks", held at IIM, Ahmedabad, January 25-30, 1993.

PLANETARY ATMOSPHERE AND AERONOMY

Dr. D.K. Chakrabarty

Mr. M. Lal

Charlottesville, Virginia, USA

1992 International Quadrennial Ozone Symposium, June 4-13, 1992.

Dr. A. Jayaraman

Dr. R. Sridharan

Dr. S.A. Haider

Washington D.C. USA

29th COSPAR Meetings - World Space Congress, August 28 - September 5, 1992.

Dr. A. Jayaraman

Carqueiranne, France

NATO - Advanced Study Institute on The Role of Stratosphere in Global Change, September, 1992.

Dr. B.H. Subbaraya

Mr. Y.B. Acharya

Dr. A. Jayaraman

Mr. S. Ramachandran

Mr. Y. Bhattacharya

Ahmedabad

Fourth Annual Conference of Indian Aerosol Science and Technology Association, October 12-13, 1992.

Dr. B.H. Subbaraya

Dr. A. Jayaraman

Dr. S.P. Gupta

Dr. R. Sridharan

Dr. R. Sekar

Dr. Harish Chandra

Mr. R. Narayanan

Mr. S. Gurubaran

Mr. D. Pallam Raju

Ahmedabad

58th Annual Meeting of the Indian Academy of Sciences, November 6-9, 1992.

Mr. S. Venkataramani

Mr. Y. Bhattacharya

Delhi

Winter School on Understanding the Climate and its future change over the Indian Sub-continent due to Global Warming, December 7- 24, 1992.

Dr. S.P. Gupta

Ahmedabad

International Workshop on Helioseismology, January 4-8, 1993.

Dr. B.H. Subbaraya

Dr. Shyam Lal

Dr. A. Jayaraman

Bangalore

First Workshop on ISRO-BP Results, February 25-26, 1993.

Dr. B.H. Subbaraya

Dr. Shyam Lal

Dr. A. Jayaraman

Mr. Manish Naja

Bangalore

First Workshop on ISRO-GBP Results, February 25-26, 1993.

Dr. B.H. Subbaraya

Dr. Shyam Lal

Dr. A. Jayaraman

Dr. Harish Chandra

Dr. H.S.S. Sinha

Mr. Y.B. Acharya

Ahmedabad

Seminar on Meteorology and Technology Transfer, 22 March 1993.

Dr. B.H. Subbaraya

Prof. Vijay Kumar

Dr. S.P. Gupta
Dr. R. Sekar
Dr. A. Jayaraman
Dr. Shyam Lal
Dr. R. Sridharan
Dr. G. Subramanian
Dr. D.. K. Chakrabarty
Dr. H.S.S. Sinha
Dr. Harish Chandra
Dr. K.P. Subramanian
Dr. G.D. Vyas
Mr. R. Narayanan
Mr. R.N. Misra
Mr. S.R. Das
Mr. Y.B. Acharya
Mr. S. Gurubaran
Mr. D. Pallam Raju
Mr. S. Ramachandran
Mr. Y. Bhattacharya
Mr. Manish Naja

Ahmedabad

K.R. Ramanathan Birth Centenary Celebrations - Symposium on Futuristic Perspective in Aeronomy and Atmospheric Science Resolution in India, March 23-24, 1993.

Mr. V. Prahlad
Mr. P. Rawat

Roorkee

Second SERC School on Atomic and Molecular Physics, March 1993.

EARTH SCIENCES AND SOLAR SYSTEM STUDIES

Geocosmophysics

Dr. N. Bhandari

Tokyo, Japan

Symposium on Antarctic Meteorites, National Institute of Polar Research, August 17-20, 1992.

Dr. N. Bhandari
Dr. S.K. Bhattacharya
Dr. S. Krishnaswami
Dr. R.K. Pant
Dr. A.K. Singhvi

Kyoto, Japan

International Geological Congress, August 24-3rd September 1992.

Dr. N. Bhandari
Dr. R.K. Pant

Shimane, Japan

International Symposium on Himalayan Geology, September 3-9, 1992.

Dr. N. Bhandari
Dr. J.N. Goswami
Dr. S. Krishnaswami
Dr. B.L.K. Somayajulu

Ahmedabad

Annual Meeting of the Indian Academy of Sciences, PRL, November 6-9, 1992.

Dr. N. Bhandari
Dr. S.K. Bhattacharya
Dr. J.N. Goswami
Dr. S. Krishnaswami
Dr. R. Ramesh
Dr. A.K. Singhvi
Dr. B.L.K. Somayajulu
Dr. T.R. Venkatesan

Ahmedabad

K.R. Ramanathan Centenary Symposium, PRL, March 23-24, 1993.

Dr. S.K. Bhattacharya

Heidelberg, Germany

Research Co-ordination Meeting, November 2-5, 1992.

Dr. S.K. Bhattacharya
Dr. R. Ramesh

Pune

Workshop Meeting on Thrust/gap areas in Paleoclimatology at IIIM, January 21-22, 1992.

S. Chakraborty

Puerto Rico, USA

Workshop on Coral-based climatic reconstruction, November 5-8, 1992.

Mr. S. Chakraborty
Dr. R. Ramesh
Dr. M.M. Sarin
Dr. B.L.K. Somayajulu

Goa

Symposium on Aspects of Chemistry of the northern Indian Ocean, August 28, 1992.

Dr. J.N. Goswami

Ahmedabad

Instructional Workshop on Helioseismology, PRL, January 4-8, 1992.

Dr. V.N. Nijampurkar

Nepal

International Symposium on Snow and Glacier hydrology, Kathmandu, November 16-21, 1992.

Dr. K. Pande

New York, USA

International Conference on Mountain uplift, chemical weathering and climate, LDGO, November 9-10, 1992.

Dr. R. Ramesh

Dr. B.L.K. Somayajulu

Bangalore

First Workshop on ID/GBP results, February 25-26, 1992.

Dr. R. Ramesh

Ahmedabad

Seminar on Meteorology & Technology transfer, SAC, March 22, 1993.

Dr. M.M. Sarin

England, UK

ECSA/ERF Conference on Estuaries, Plymouth, September 13-18, 1992.

New Delhi

Workshop on River basins of India, JNU, March 23-24, 1993.

Dr. A.K. Singhvi

Iran

Seminar on desert problems and saline playas, May 15-19, 1992.

Jodhpur

National Seminar on Environment, January 27-30, 1992.

Dr. B.L.K. Somayajulu

Pune

33rd Annual Meeting of the Geological Society of India, September 21-23, 1992.

Continental Palaeoclimate Studies

Dr.D.P.Agrawal

Shimane, Japan

Symposium on Himalayan Geology, September 6-8, 1992.

Kyoto, Japan

ternational Symposium on Nature and Humankind in the age of environmental crisis, September 28 - October 4, 1992.

New Delhi

Indian Institute of Technology, Winter School, November, 1992.

Dharwar

Annual Congress of Indian Society for Prehistoric and Quaternary Studies, November 1992.

Pune

Workshop on Past Global Climatic changes, January 21-22, 1993.

Mombasa, Kenya

Conference on origin of urbanisation in East Africa, January 25-29, 1993.

Dr.S.K.Gupta

Hong-kong

Western Pacific Geophysics Meeting, AGU. August 17-21, 1992.

THEORETICAL PHYSICS

Dr. A.R. Prasanna

October 14-November 4, Academic Director, U.G.C. Advanced Graduate School in Relativistic Astrophysics, Gravitation and Cosmology. Also gave course on General Relativity and Accretion dynamics.

Dr. Sai Iyer

Pune

IUCAA Dedication Symposium, December 28-30, 1992, Inter-University Centre for Astronomy and Astrophysics, Pune.

Dr. V. Satyan

Mr. B. Thomas

Ahmedabad

Indian Academy of Sciences, 58th Annual Meeting, Physical Research Laboratory, November 6-9, 1992.

Mr. B. Thomas

Bangalore

Workshop on PARUL: Parallel User Library at CDAC, December 1, 1992.

Dr. V. Satyan

Bangalore

First Workshop on ISRO-GBP results, ISRO Head Quarters, February 25-26, 1993.

Delhi

TROPMET-93, National Symposium on Meteorology and National Development, National Centre for Medium Range Weather Forecasting, March 17-19, 1993.

Dr. V. Satyan

Mr. S.V. Kasture

Ahmedabad

Seminar on Meteorology and Technology Transfer, Space Applications Centre, March 22, 1993.

Dr. V. Satyan

Mr. S.V. Kasture

Mr. B. Thomas

Ahmedabad

K.R. Ramanathan Centenary Symposium on Futuristic Perspectives in Aeronomy and Atmospheric Science Research in India, Physical Research Laboratory, March 23-24, 1993.

Dr. B. Buti

Palanpur

Seminar on Horticulture in India: Perspective held at Palanpur on May 13, 1992.

Calcutta

Seminar on Current Status and Future Persepctives of High Energy Physics in India held at VEC Centre, Calcutta on August 4, 1992.

Hong Kong

Conference on Nonlinear Dynamical Aspects of Space Plasmas held at Hong Kong during August 17-22, 1992.

New Delhi

Conference on Forestry Research and Education in India held at INSA, New Delhi, during October 8-9, 1992.

Bombay

Seventh National Symposium on Science and Technology of Plasmas held at Bombay University during November 3-7, 1992.

Kuwait

TWAS (Third World Academy of Sciences) Fourth General Conference held at Kuwait during November 23-26, 1992.

Seminar on Fisheries and Acquaculture held at INSA, New Delhi, on December 28, 1992.

Dr. A.C. Das

Ahmedabad

58th Annual Meeting, Indian Academy of Sciences, Ahmedabad, November. 6-9, 1992.

Hong Kong

1992 WPGM Meeting, Hong Kong, August 17-21, 1992.

Bombay

Plasma-92, 7th National Symposium on Science and Technology of Plasmas, University of Bombay, Bombay.

Dr. N.N. Rao

Bombay

VII National Symposium on Science and Tenchology of Plasmas, University of Bombay, November 3—7,

1992.

Ahmedabad

Instructional Workshop on Helioseismology, Physical Research Laboratory, January 4—8, 1993.

Ahmedabad

Symposium on Futuristic Perspectives in Aeronomy and Atmospheric Science Research in India, Physical Research Laboratory, March 23—24, 1993.

Dr. D.P. Dewangan

Roorkee

Second SERC School in Atomic and Molecular Physics - Ion-atom/molecule collisions. March 22-April 10, 1993, Roorkee University, Roorkee, U.P.Gave a course of 6 lectures on Electron capture in energetic ion-atom collisions.

Dr. V.B. Sheorey

Bombay

IX th National Conference on Atomic and Molecular Physics, Bombay, December 14 -18, 1992.

Tempe, Arizona, USA

XII th Annual International Conference Dynamic Days Arizona, Tempe, Arizona, USA, January 6 - 9, 1993.

Dr. A.S. Joshipura

Dr. B. Ananthanarayanan

Trieste

Summer School on High Energy Physics and Cosmology, I.C.T.P., Trieste, Italy, July-August 1992.

Dr.Y.D. Devi

Dr.V.K.B. Kota

Puri

IUCDAEF(Calcutta Centre) Workshop on Nuclear Structure Physics, Puri, March 5-7, 1993

Dr.V.K.B. Kota

Tirunelveli

Symposium on Recent Trends in Nuclear Physics, March 15-18, 1993.

Dr. A.K. Rath

Dr. K.B.Vijaya Kumar

Mr D. Majumdar

Bombay

DAE Symposium on Nuclear Physics, December 21-24, 1992.

Dr. S.D. Rindani

Dr. Utpal Sarkar

Dr. J.C. Parikh

Mr. P. Poulos

Mr. G. Datta

Mr. B. Brahmachari

Mr. M.K. Samal

Bombay

X DAE Symposium on High Energy Physics, TIFR, Bombay,December 25- 28, 1992.

Dr. B. Ananthanarayan

Dr. Utpal Sarkar

Mr. M.K. Samal

Mr., B. Brahmachari

Puri

BCSPIN Winter School on High Energy Physics and Cosmology, January 2- 21, 1993.

Dr. Utpal Sarkar

Dr. S.B. Khadkikar

Trieste, Italy

"SALAMFEST" : Symposium on Condensed Matter Physics and Particle Physics.

Dr. S.B. Khadkikar

Bombay

Quark Gluon Plasma Workshop at T.I.F.R., Bombay, April 6-19, 1992.

Wiesbaden, Germany

International Nuclear Physics Conference, Wiesbaden, July 26 to August 1, 1992.

COMPUTER CENTRE

Mr.P.S.Shah

Madras

27th CSI Annual Convention, September 1992.

Mr. M.S.Patel

Madras

27th CSI Annual Convention, September.,1992.

ELECTRONICS LABORATORY

Mr. H.S. Mazumdar

Hyderabad

IEEE Conference on VLSI VLSI'93 January3-6, 1993, Indian Computing Congress, December1992.

Dr. S.N. Pradhan

Ahmedabad

IEEE, International Conference on Computer Networks (ICCN-92), February 19-21, 1993.

LIBRARY

Mrs. Rhoda Bharucha

Delhi

58th IFLA General Conference, August 30-September 5, 1992.

Bombay

FORSA Meeting during 15th ASI Meeting, BARC, Bombay March 2- 5,1993.

Visits to Universities/Research Organisations and Talks given there in 1992-93

ASTRONOMY AND ASTROPHYSICS

Dr.A.Bhatnagar

Mitaka, Japan.

Visited National Astronomical Observatory, Solar Division and gave a talk on Magnetic Field Configuration Solar Flare Loops and Eruptive Flares during September 1-4, 1992.

Calcutta, India

Visited Birla Institute of Astronomy and Planetarium Sciences and gave 8 talks on Introduction to Solar Physics, during February 18-26, 1993.

Dr.Debi Prasad C.

Pune, India

Visited IUCAA, and gave a talk on Recent Trends in Optical Spectroscopy in Astronomy at Summer School held in June, 1992.

Visited Regional Science Centre and gave a talk on Probing into the Sun, Stepember 5, 1992.

Dr.J.N.Desai

New Delhi, India

Visited National Physical Laboratory, New Delhi during Dec.1-Decembe 1- 31, 1992. Gave a series of 4 lectures covering i) Fabry-Perot Spectroscopy in Astronomy & Astrophysics & ii) Stellar Scintillations & Atmospheric Turbulence.

Dr.U.C.Joshi

Nainital, India

Visited U.P.State Observatory, Nainital (India).Gave a Colloquium at U.P.State Observatory, Nainital on Variability in BL Lac Objects.

Dr.S.C.Tripathy

Visited North Bengal University and conducted tutorials Plasma Astrophysics at the Winter School on Relativistic Astrophysics during October 14-November 2, 1992.

Dr. Hari Om Vats

Allahabad, India

Visited J.K. Institute of Applied Physics, and gave two talks on: IPS Radio Telescope, on April 10, 1992, and "Solar Wind" on April 15, 1992.

Visited Physics Department, Allahabad University and gave a talk on Our Universe on April 13, 1992.

Visited Earth & Planetary Science, Allahabad Univ. and gave 3 talks on (1) Evolution of Universe", on April 17, 1992, (2) Basics of a Radio Telescope on April 18, 1993 and (3) Interaction of Solar Wind with the Earth's Magnetic Field, on April 19, 1993.

Pune, India

Visited GMRT project during July 22-25, 1992 and gave a talk there on IPS Studies at 103 MHz, on July 23, 1992.

Boulder, Co. (USA)

Visited Space Environment Laboratories/PRL, NOAA, during August 29-September 4, 1992 and gave a talk on "Interplanetary Scintillation Studies" on September 3, 1992.

New Delhi, India

Visited National Physical Laboratory and gave a talk on Terrestrial Effects of a Pulsar, on November 25, 1992.

Ahmedabad, India

Visited National Institute of Design (NID), and gave a talk there in Hindi on Universe; A Scientific View

PLANETARY ATMOSPHERE AND AERONOMY

Dr. B.H. Subbaraya

Coimbatore

Gave 2 lectures on Recent Developments in Stratospheric Chemistry and Boundary Layer Exchange Processes in the earth's atmosphere, Airforce Met Training Centre,April 22-23, 1992.

Dr. H. Chandra

BHU, Varanasi

Gave two lectures on Spaced Receiver Technique" and "Power Spectral Analysis of Scintillation Data, June 1-5, 1992.

Dr. D.K. Chakrabarty

Washington D.C., USA

Gave a talk on Can negative ion Chemistry Explain Ozone ? - Hole at the Antarctica and held long discussion on How SST Aircraft Emission can Increase Ozone in the Upper Atmosphere, Centre for Remote Sensing, June 14-15, 1992.

Seattle, USA

Gave a talk on Ion Conductivity and Ion Chemistry of the Middle Atmosphere, Physics Department, Unicersity of Washington June 16-17, 1992.

Dr. S.P. Gupta

Bangalore

Gave a talk on Global Electric Circuit - Future Prospectives, Department of Aeronautical Engineers Indian Institute of ScienceJune 23, 1992.

Dr. A. Jayaraman

Princeton, USA

Gave a talk on Atmospheric Aerosols, Ozone and Trace Gases Measurements in India, Gep[hysical Fluid Dynamics Laboratory - NOAA, September 8, 1992.

Dr. B.H. Subbaraya

Mysore

Gave a talk on Stratospheric Chemistry and Ozone Depletion Problem, Mysore University, October 8-9, 1992.

Dr. Harish Chandra

Rajkot

Gave 14 lectures on Atmospheric Physics/Ionospheric Physics, Saurashtra University.

EARTH SCIENCES AND SOLAR SYSTEM STUDIES

Geocosmophysics

Dr. S.K. Bhattacharya

Calcutta

Gave two invited lectures on isotopes and palaeo-oceanography in the School of Oceanographic Studies, Jadavpur University, on March 23, 1993.

Gave an invited talk on Isotope Techniques in Earth Sciences at the Centre for Study of Man and Environment on March 30, 1993.

Dr. J.N. Goswami

Guwahati

Gave a talk in June 1992 in the Physics Dept. on Meteorites and Early Solar System.

Dr. K. Pande

New Haven, CT, USA

Visited the Dept. of Geology & Geophysics during November 12-16, 1992 and gave a talk on ^{40}Ar—^{39}Ar Chronology of Deccan Traps and K/T events.

Udaipur

Visited the Geology Dept. of the Sukhadia University and gave 3 lectures on Applications of Mass Spectrometry in Earth Sciences during January 23-26, 1993.

Dr. R. Ramesh

San Diego, USA

Visited the Scripps Institution of Oceanography and gave a talk on Monsoon Signatures in Trees, Corals and Deep Sea Sediments on May 15, 1992.

Mr. Someswar Rao

Nagpur

Gave a talk on Applications of Thermoluminescence in the Physics Department of the Nagpur University in October 1992.

Dr. M.M. Sarin

Delaware, USA

Visited the College of Marine Studies, University of Delaware in Newark and gave two lectures in June 1992.

New Delhi

Visited the School of Environmental Sciences and JNU and gave a colloquium on Natural Rdio nuclides in the Arabian Sea : Scavenging Rates and Cycling Processes in March 1993.

Dr. A.K. Singhvi

Osaka, Japan

Visited the Earth Sciences Dept. of the Osaka University during September 4-7, 1992 and gave a talk on Luminescence Dating in Quaternary Sciences - Present Status.

Dehradun

Visited the Wadia Institute of Himalayan Geology during January 19-23, 1993 and gave a talk on Luminescence Dating : Principles, Application and Present Status.

Roorkee

Visited the Earth Sciences Dept. of the Roorkee University during July 23-25, 1992 and gave a talk on Luminescence dating.

Continental Palaeoclimate Studies

Dr. D.P. Agrawal

Shimane, Japan

Visited Shimane University, Shimane, Japan and gave public lecture on IGBP Related Lake Studies in India. September 9, 1992.

Kyoto, Japan

Visited Kyoto University, Kyoto, and gave a talk on Palaeoclimate and Palaeoenvironmental Changes during the Last Four Million Years in India.

New Delhi, India.

Visited the Institute of Archaeology and gave four talks on Science and Archaeology, March 1993.

Dr. Sheela Kusumgar

Bhubaneshwar, India.

Visited the Institute of Physics and gave a talk on Carbon-14 Dating and Need for AMS in India, Sept.ember 14-18, 1992.

THEORETICAL PHYSICS

Dr. A.R. Prasanna

New Delhi

April 21-24, School of Physical Sciences, Jawaharlal Nehru University, Delhi. Gave three talks on(i) Accretion Dynamics and (ii)Centrifugal Force Reversal

Mysore

August 10, Dept. of Physics, Mysore University. Gave a semi popular talk on 'Centriufgal Force Reversal'.

Madras

August 22-24, Institute of Mathematical Sciences, Madras. Gave a seminar on 'Centrifugal Force Reversal in General Relativity'.

Mr. S.V. Kasture

Ahmedabad

Department of Physics, Gujarat University. Gave a course on Dynamical Meteorology in December 1992-January 1993.

Dr. B.Buti

Calcutta

Saha Institue for Nuclear Physics. Gave a talk on Coherent and Chaotic Phenomena in Magnetosplasmas in August, 1992.

Bhubaneshwar

Institute of Physics at Bhubaneswar. Gave 2 lectures on Chaos in Plasmas and Stochastic Particle Acceleration in September, 1992.

Trivandrum

Vikram Sarabhai Space Science Centre at Thumba. Gave Jawaharlal Nehru Birth Centenary Lecture on Coherence in Chaos in February 1993.

Cochin

Physics Department of Cochin University. Gave a talk on 'Chaos in Plasmas' in February 1993.

Bombay

Indian Institute of Geomagnetism. Gave a talk on 'Nonlinear Evolution of Alfven Waves' in February 1993.

Dr. V. B. Sheorey

Pune

Department of Physics, University of Poona, Pune. Gave a seminar on "Localised Chaotic Quantum States", (March 30 -31, 1992)

Cambrdige, MA, USA

Institute of Theoretical Atomic and Molecular Physics, Harvard - Smithsonian Center for Astrophysics, Harvard University. Gave a seminar, "Structures in Wavefunctions of a Chaotic Quantum Syatem" , (January 17 - February 20, 1993).

Ithaca, NY, USA

Baker Laboratory of the Department of Chemistry, Cornell University. Gave a seminar, "Localisation in Chaotic Quantum Systems", (March 1 - 2, 1993).

Kingston, NY, USA

IBM Parallel Supercomputing Laboratory. Gave a seminar, "Chaotic Quantum Systems", (March 3 - 4, 1993).

Dr. Y.D. Devi

USA

Center for Theoretical Physics, Sloane Physics Laboratory, Yale University. Gave a talk at Wright Nuclear Structure Laboratory, Yale University on "sdg Interacting Boson Model: Hexadecupole Degree of Freedom in Nuclear Structure", during September- November 1992.

Department of Physics, Rutgers University, New Braunswick. Gave a talk on "sdg Interacting Boson Model: Hexadecupole Degree of Freedom in Nuclear Structure", during 23-24 November 1992.

Department of Physics, Drexel University, Philadelphia. Gave a talk on "sdg Interacting Boson Model: Hexadecupole Degree of Freedom in Nuclear Structure", during 1-2 December 1992.

Canada

Department of Physics, Laurentian University, Sudbury. Gave a talk on "sdg Interacting Boson Model: Hexadecupole Degree of Freedom in Nuclear Structure", during 9-11 December 1992.

Dr. S.D. Rindani

Kathmandu, Nepal.

Delivered a series of 12 lectures on "The Standard Model" in the preparatory school for BCSPIN participants at Tribhuvan University, October, 1992.

Dr. A.S. Joshipura

Switzerland

CERN, Geneva, Switzerland during August-September 1992. Gave a talk on "MeV Neutrinos and Seesaw Models".

Germany

Inst. fur Theoretische physik, Hamburg, Germany during October- December 1992. Gave a talk on "Majoron Model at the Weak Scale".

University of Dortmund, Germany. Gave a talk on "Majoron Model at the Weak Scale".

Dr. U. Sarkar

Santiniketan

Physics Department, Visva-Bharati University. Gave a seminar on "Neutrino - status Report".

Calcutta

S N Bose National Center for Basic Sciences. Gave a talk on "Neutrino Mass and Solar Neutrino Puzzle".

Honolulu, Hawaii, USA

Physics Department, University of Hawaii. Gave a seminar on "LEP Constraints on the Left-right Symmetric Extensions of the Standard Model" on March 31, 1993.

Dr. S.B.Khadkikar

Bombay

TIFR. Gave a talk on 'A Deductive Theory of Strong Interaction'.